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Research Article

A Comparative Study Of Secondary Science Curriculum Between India, China And Japan

Ajoy Ghosh[1*], Dr. Aniruddha Ray[2]

[1*]Department of Education, Swami Vivekananda University, Barrackpore, India
[2]Professor, Department of Education, Swami Vivekananda University, Barrackpore, India

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ARTICLE INFO | **ABSTRACT**

Modernization of secondary science education is mostly dependent on curriculum reforms through policy recommendations. The two East Asian countries China and Japan started their science modernization at the end of twentieth century and for the last few years these two countries are performing outstandingly in the international science competitions like Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA). Various studies from OECD revealed that Chinese and Japanese science curriculums are very much aligned with the 21st century appropriate modern curriculum. This study analyzes and provides a deep understanding of secondary science curriculum and middle and secondary stage science curriculum objectives and recent changes in curriculum reform and implementation process. For this qualitative comparative study deductive content analysis method was followed. Major findings of this study revealed that the curriculum reform system of India and China is more centralized compared to Japan. Although the three countries follow integrated science curriculum approach at the lower secondary level (for China and Japan) and middle and secondary phase I (for India), Chinese curriculum objectives have emphasized on students' holistic development through science core competencies whereas Japan prioritized on physics topics and India has given almost equal importance on physics, chemistry and biology topics. Japan's curriculum reform is more frequent and systematic than India and China. Three aspects of Japan's lower secondary science curriculum objectives are 'knowledge', 'attitude' and 'ways of thinking'. Main curriculum objectives (of NCF-SE, 2023) at middle stage and secondary science in India are 'gaining scientific knowledge' through Indian rootedness, and 'obtaining scientific temper and attitude' and focused on creativity and innovation through students' learning outcome. Both China and Japan have included STEM education in the secondary science curriculum and achieved success through STEM approach, whereas Indian secondary science curriculum does not include STEM education.

Key words: secondary science curriculum, curriculum reform, curriculum objectives, STEM education

1. Introduction:

The Organization for Economic Co-operation and Development (OECD) has advocated for making curriculum reforms with clear description of curriculum objectives on the basis of 21st century appropriate skills of the students like knowledge, attitudes, values and competencies. OECD in their working paper also mentioned that curriculum reform and implementation system is changing from 'top-down' approach (where Government is the supreme authority and teacher has minimum power or role) to the 'bottom-up' approach (where teacher has the central role) (Working paper no. 239, OECD, 2020a).Curriculum alignment is a vital aspect of reducing curriculum burden on the students. If there is no clear description of changes with specific objectives at the time of curriculum transformation, this may mislead the teachers for implementing the new curriculum in a proper way (Voogt et al., 2017). To find out the common goals of education in the aspects of learning progression or future learning directions, many studies in science and mathematics education have been administered empirically by Gotwals &

Alonzo (2012) and Yao & Guo (2018a). Such learning progression related research findings became helpful for generating the science education standard for the future as "Next Generation Science Standard" ([NGSS]; NGSS Leads, 2013). Researches in this area became popular worldwide by offering a coherent design for uniting various aspects of education viz. curriculum instruction and assessment altogether (Lehrer & Schauble, 2015).

OECD has published a position paper in 2015, named as "The Future of Education and Skills Education 2030" to help in framing up an organized realistic curricula aligned with the international trends for curriculum reform (OECD, 2018). This type of realistic curricula will be helpful for designing rich teaching materials, curriculum standards and producing good textbooks for developing students' required knowledge with appropriate skills for acquiring their better life within 2030 (OECD, 2018). OECD, after rigorous study with 14 countries, structured the Curriculum Content Mapping (CCM) of OECD Education 2030 on the basis of OECD Learning Framework 2030 (OECD, 2019). In OECD's CCM, various curriculum competencies are categorized as shown in (Table 1)

Table (1): Categorization of Curriculum Competencies in OECD's CCM framework

Categories of Curriculum Competencies	Subcategories
Foundational literacy	Literacy, ability to understand simple numerical concepts, Digital literacy or basic knowledge in ICT, Data literacy, Health related literacy
Values, attitudes and skills	Cooperating/collaborative approach, thinking critically, problem solving ability, disciplined or self-regulation, respect for others, empathy, continuity, honesty.
Important concepts	Student agency i.e. students act as agent for fruitful learning, and co-agency i.e. mutual supporting relationship with peers, teachers, parents and society
Transformational competencies and competency for lifelong development by 2030	Generating unique values, acknowledging and accepting responsibilities, taking right decision at the conflicting situation, strong belief of expectancy, activities, and contemplation.
Composite competencies for 2030	Universal competency, digital competency, media literacy, knowledge about sustainable future, problem solving ability for programming and coding different digital tools, leadership ability.

Secondary stage 4 years (age 14 to 18 years)	Phase II: 2 years (Grades 11 & 12)
	Phase I: 2 years (Grades 9& 10)
Middle stage	3 years: (Grades 6, 7 & 8) (age 11 to 14 years)
Preparatory stage	3 years: (Grades 3, 4 & 5) (age 8 to 11 years)
Foundational stage	2 years: (Grades 1 & 2) (age 6 to 8 years)
	3 years (anganwadi / preschool / balvatika) (age 3 to 6 years)

Table (2a): School education structure in India (taken from NEP, 2020)

Upper secondary education	3 years: Grades 10 to 12 Upper secondary education at regular senior high schools (age 15 to 17 years)
Compulsory education (age 6 to 14 years)	3 years: Grades 7 to 9 (stage 4) Lower secondary education at junior secondary schools
	6 years: Grades 1 to 6 (Stage 1, 2 and 3) Elementary school education

Table (2b): School education structure in China (taken from OECD, 2016)

Secondary education	3 years of upper secondary education: Grades 10 to 12 (age 15 to 18 years)
	3 years of lower secondary education: Grades 7 to 9 (age 12 to 15 years)
Primary education	6 years of elementary school: Grades 1 to 6 (age 6 to 12 years)
	3 years of nursery school (Preschool or kindergarten education) (age 3 to 6 years)

Table (2c): School education structure in Japan (taken from MEXT, 2017-18)
The grade and age specific school education structure in India, China and Japan are shown in Figures 2a, 2b and 2c.

1.1 Significance of the study: This study analyzes comparatively the science curricula regarding the aspects of curriculum objectives, curriculum standards, curriculum reform, and curriculum implementation strategy in the three selected countries. Japan and China are two top-performing countries considering students achievements in the assessments conducted internationally like Program for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), etc. On the other hand India had participated once in PISA 2009 and the students performed extremely poor and after that, they did not participate again. So, the Chinese and Japanese education system being the forerunners are considered as the education systems of global benchmarks. All three Asian countries started their science education development journey almost in the same period but which features and implementing approach became helpful for China and Japan's excellence in international assessments in the last few decades is the major concern of this research. The researchers also inspired how the learnings from less centralized and one of the most industrialized countries Japan's curricular reforms might be benefited for two developing countries with more centralized education systems in China and India.

1.2 Historical overview of secondary science curriculum:

1.2.1 India:

Since independence in India several commissions viz. University Education Commission (1948) first emphasized on inclusion of general science as a course in the secondary level, Secondary Education Commission (1953) recommended for mandatory science subject teaching in both secondary and higher secondary levels and the Education Commission (1964) advocated for inclusion of science as environmental science starting from the primary level. The National Council of Educational Research and Training (NCERT, established in 1961) has set up the science education department for monitoring the school science education system. According to the recommendation of NPE-1968 "Science Education should be an integral part of general education"

NPE-1986 addressed as "Science Education for All". NCERT published three different National Curriculum Frameworks (NCF) in the years 1986, 2000, and 2005. NCF-2005 provided the framework for present school education programs like making syllabi, textbooks, and teaching practices in Indian schools. Very recently NCERT has published the NCF of school education (NCF-SE) for school children aged between 3-18 years. NCF-SE (2023) has made huge changes in the curricular and pedagogical aspects maintaining the NEP-2020's recommendations following the new school education structure (5+3+3+4) (as shown in Table 2a).

The new policy document was introduced by Ministry of Human Resource Development (MHRD) as National Educational Policy 2020 (NEP-2020). NEP-2020 advocated for reforming science education as global standard in the areas of innovative pedagogy, learning outcomes, flexible curriculum approach (reform and implementation) with the main focus on creativity and innovation.

1.2.2 China:

Since the formation of People's Republic of China (PRC), China has gone through eight curriculum transformations from time to time (Yin, 2013) and the very recent curriculum reform (ninth) was introduced in 2022 (MOE, 2022). MOE, in 2001, announced the eighth curriculum reform as the "*Compendium of Curriculum Reform for Basic Education (experimental)*" for helping nation's progress through student's own development (MOE, 2001). The eighth phase of curriculum reform was emphasized on quality of education (Yin, 2013) and this was the first modernized form of curriculum and had opened the platform for learning

through mutual co-operation between western and Chinese cultures in an era of globalization (Luo, 2023).
From 1980s to 1999 Chinese science education had gone through a revolutionary curriculum change in primary, lower secondary and upper secondary levels. The school and curricular structure of China is represented in the Table (2b). Ministry of Education (MOE) in 2001 introduced a plan as the “Framework for Basic (i.e., primary and secondary) Education Curriculum Reform”. MOE published a national science curriculum standard at the primary level (for grades 3-6), at the lower secondary level (grades 7-9) both for integrated science curriculum (junior high schools where physics, chemistry and biology taught as integrated science) and discipline based science curriculum (Junior high school science where chemistry, physics and biology are taught as individual subject). In 2003, MOE published the curriculum standards for Physics, Chemistry, and Biology for upper secondary level (grades 10-12) (Bangping, 2015)
China has implemented several policies and action plans such as “Guidelines for National Science Literacy Action Plan (2006-2010- 2020)”, “Implementation of National Science Literacy Action Plan (2016-2020)”, “National Science Literacy Action Plan” (hereafter the 2049 plan) etc. for the purpose of enhancing and inculcating scientific literacy among K-12 children and for all Chinese citizens (Liu et al., 2017)
MOE started their ninth curriculum reform related processing since 2014 giving importance on core competencies as shown in Figure (1) (Wang, 2019) and to inculcate necessary qualities like moral character, and to develop critical thinking abilities required for lifelong development of self as well as for society (Luo, 2023). For example, MOE’s 2022 curriculum standard advocated for core competencies in physics curriculum like key concepts in physics, understanding physics by scientific inquiry and thinking scientifically, scientific spirits and attitudes (MOE, 2022). China has multiple types of science curriculum development process due to the existence of various ethnic groups and for their past history. Compulsory science education curriculum standards and relevant textbooks are fully controlled by central government of China.

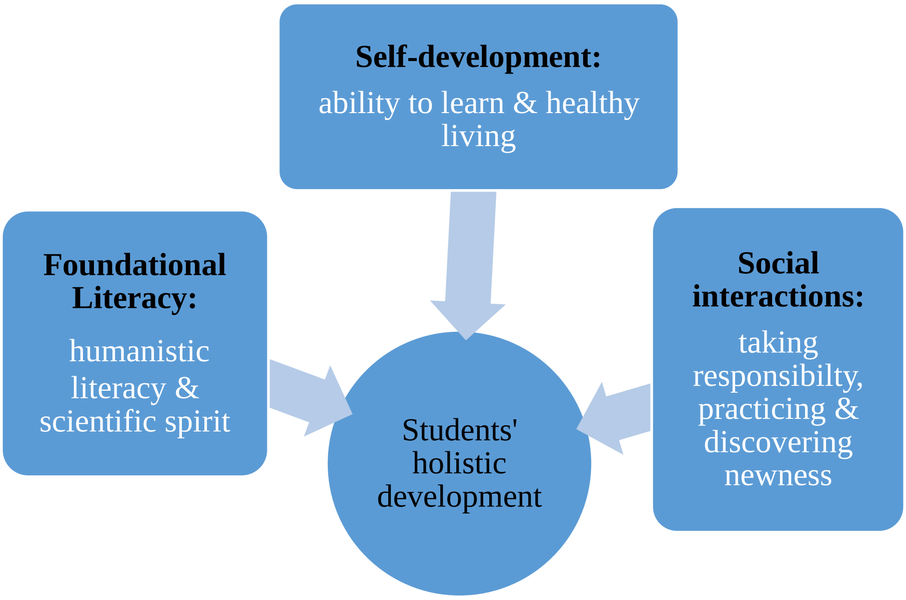

Figure (1): Chinese students’ development through core-competencies

1.2.3 Japan:

Japan started their curriculum reform for the 21st century appropriate education system since 1980s and became very much successful within very small period of time. This is due to mainly three reasons viz. Japan’s highly centralized education system, uniformity in language nationally and very high literacy among Japanese citizens (Isozaki and Pan, 2016).
MEXT introduced the super science high schools programme (SSH) in 2002 and presently this project aims to i) create innovative and enriched curriculum in science and mathematics, ii) promote collaborative research activities and link and apply the outcome in upper secondary schools iii) to foster globalization of science education iv) develop pedagogical innovations including teaching materials and methods for better understanding of science and mathematics (Japan Science and Technology Agency, n.d.)
OECD (2018) pointed out that Japan has a high quality education system including science education and this was reflected in the scientific literacy of the students in the OECD’s Programme for International Student Assessment (PISA) tests. OECD mentioned in this report one of the vital aspect for fruitful transition of education reform is adaptation through new curriculum by changing the teaching learning practices, assessments of students and changing pattern of university entrance examinations accordingly (OECD, 2018).
Japan implements their curriculum reforms regularly almost in every ten years interval. The last two

curriculum reforms in the 2000s and 2010s helps Japanese students perform with excellence by securing 6th, 5th 4th and 2nd rankings in PISA 2006, 2009, 2012 and 2015 respectively in science (Yamanaka and Suzuki, 2020).

	India	China	Japan
Curriculum program or policies of school education	National Curriculum Framework for School Education (NCFSE). National Education Policy (NPE or NEP)	Compulsory Education Curriculum Program and Standards (2022 edition) (Ministry of Education, 2022)	National Curriculum Standard for Lower Secondary Schools. National Curriculum Standard for Upper Secondary Schools
Role of government and other centers	Central government makes policies and National Curriculum Framework (NCF) Individual state governments have the autonomy and flexibility for implementing NCF. State governments make policies and gives educational support to public schools by NCERT. Private schools follow government policies but work independently	Ministry of Education of China makes policies and national curriculum. State governments make policies and monitor public schools. Municipal and provincial governments have the right to select the contents of the syllabus including secondary science subjects.	MEXT under the guidance of central government of Japan makes policies and national curriculum standard. Local boards of education (local governments of different municipalities) have the freedom and flexibility to implement the national curriculum standard.

Table (3): Curriculum policies and role of government and centers

2. Research Gap:

There are many studies of science curriculum reform have been done between China and Japan with other developing as well as developed countries as these two countries are top performers and forerunner of science education in the global context. But till date there is no such secondary science curriculum comparison is evident between India, China and Japan.

3. Motivation:

To fill the research gap, we have initiated to make a comparative analysis of contemporary secondary science curriculum prevalent in India, China and Japan

4. Objectives:

Major objectives of this study are

- To investigate the curriculum reform and curriculum management system existed in India, China and Japan.
- To study and analyse the contemporary secondary science curriculum of India, China and Japan and to make a comparative study.

5. Materials and Methodology

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

a) General methodology: *Qualitative study,*
b) Methodology: *Few-country comparison,*
c) Comparative method: *Content analysis and Document analysis.*
d) Research materials: *Government documents, peer reviewed journals, books, edited books, conference papers.*
e) Data collection process: *Multiple procedures consisting of studying journals (print and online), books, bookchapters, policy documents, and reports of the commissions were used.*

Data analysis: *The researchers employed a contemporary document-based analytical approach. The collected data are analysed with the help of historical and sociological strategies.*

6. Major findings:

6.1 Curriculum program and policies and role of concerned governments:

In all the three countries, the concerned central governments make curriculum policies and various governments and centres have their specific roles as shown in the Table (3).

6.2 Curriculum reforms with curriculum objectives of secondary science education:

Curriculum reform is closely related to a society/country's developments and so this developmental aspect determines and influences the changing directions of curriculum transformations (Yin, 2013). A comparative study of curriculum development in mathematics education between India and China pointed out several features of curriculum reforms existed in these two countries (Pramanik, 2019; Pramanik & Guha, 2019)

6.2.1 Indian settings: In India, education is in concurrent list and education system is diffused in nature. The central government suggests for making National Education Policy (NEP) and then according to NEP's recommendations/suggestions National Curriculum Framework for School Education (NCFSE) is developed and published by National Council of Educational Research and Training (NCERT) for all states throughout the country. There are State Educational Research and Training (SCERT) in every state, they adapts and implements the curriculum policies and standards in the respective state. However, every state has the autonomy for implementing NEP within their education system.

Curricular aims of science education in India (according to NCF-2023):

- To develop the student's understanding of basic scientific knowledge like theory, principles, laws and processes of science concept individually or through collaborative work with peers.
- To develop the ability to make prediction, argumentation, analyzes logically, taking decision and evaluate any situation by using scientific method.
- To realize and understand how the scientific knowledge and methods have evolved over time.
- To develop an understanding about the interlinkage between science and other disciplines for the realization of the world as a whole.
- To develop an understanding how science, technology and society are connected to each other in several issues including moral aspects and their significance.
- To develop a scientific temper by developing critical and logical thinking, to get rid of fear and free from prejudice, by fostering student's curiosity and creativity along with aesthetic aspects of science.
- To assimilate scientific values and characters like objectivity, morality, honesty, symbiosis and collaboration, concern for healthy life and knowledge of sustainable future.

Curricular goals and competencies of science education in India:

At the middle stage and grade 9 & 10 of secondary stage science is taught as integrated manner comprising the disciplines of physics, chemistry, biology and earth science.

Middle stage: Curricular Goals (CG) at this stage are

- CG 1: Can understand the physical and chemical properties of matter around us and their constituents.
- CG 2: Can be able to demonstrate and describe the physical world with the help of mathematical and scientific notations.
- CG 3: Can explore the living organisms scientifically.
- CG 4: Can develop the understanding of factors for good health, hygiene and welfare.
- CG 5: Can illustrate the interrelationships between society and science and technology.
- CG 6: Can explore the properties and processes of natural phenomenon with the help of scientific knowledge and curious mind.
- CG 7: Can express and represent a phenomenon scientifically by through questioning, observation and conclusion.
- CG 8: Can understand and feel proud for Indian contribution to the science from ancient time to current period through their integrated science curricula.
- CG 9: Can aware of the latest scientific discoveries and knowledge.

At the secondary level (grades 9 & 10) curricular objectives and competencies (i.e. learning standards) will be as follows

- In chemistry part students can explore matter and their chemical properties in the atomic level.
- In physics part they will learn and understand different laws and principles with the help of scientific observations and explanations.
- In biology part they can explore the structure and functions of animal and plant cells.
- Students can link their scientific knowledge with other disciplines in their curriculum.
- Students will be to achieve CG 8 & CG 9 as in middle stage but appropriate with their integrated secondary science curricula.
- Students can analyses real life events scientifically with the help of their gained knowledge through hands on experiences in the science experiments.

6.2.2 Chinese Settings:

Curricular goals of science education for compulsory level (grades 1-9) in China:

MOE's eighth phase of curriculum guideline (which was in action till June 2019) has comprised of eight competence indicators for students in grades 1-9 consisting of four stages (stage 1, grade 1-2; stage 2, grade 3-4; stage 3, grade 5-6; and stage 4, grade 7-9) (MOE, 2001). The curriculum objectives of science leaning according to eight domains are

(i) To know and understand the scientific and technological phenomena.
(ii) To expand the process skills such as scientific observation, comparison and to classification, organization and making inferences scientifically.
(iii) To make a better understanding about the nature of science.
(iv) To develop the ability of students for applying scientific knowledge and process in their daily life situations.
(v) To develop and nurture the processing intelligence skills like critical and creative thinking and scientifically problem-solving attitude.
(vi) To create a peoples' need based design and producing the required product.
(vii) To realize the developmental nature of science and technology and to link between science and technology with society.
(viii) To develop a scientific attitude like being specific and rational (for stage 4 i.e. lower secondary level).

In 2016, MOE has issued the policy for 'the core competencies and Values for Chinese Students' Development' emphasizing on students' holistic development (People's Daily, 2019) (Fig.1) and this was reflected in compulsory education curriculum program and standards (2022 edition) also (MOE, 2022).

MOE, in 2019, has published the 'Guideline on Deepening the Reform of Education and Teaching and Comprehensively Improving the Quality of Compulsory Education' aiming to develop the holistic development of the students. The new guideline addressed some vital points

- To develop moral aspects, feelings of excellent Chinese traditional culture and shaping mental health fruitfully through the curriculum including science.
- To develop intellectual aspect like cognitive ability and innovative aptitude of the students.
- To encourage the hard working spirit of the students, the guideline has emphasized on physical education (The State Council, 2019).

6.2.3 Japanese settings:

Japanese school education system consists of 6 years of primary level, 3 years of lower secondary level and 3 years of upper secondary level (Table 1c). For all the students a common mandatory science and mathematics program and curriculum is prescribed and followed by all public primary and lower secondary schools.

In Japan, the national curriculum standards at school levels (including secondary level) in the form of course of study is set and published by Ministry of Education, Culture, Sports, and Technology (MEXT) for each types of schools (MEXT, 2017a).

Overall Curricular goals of science education at lower secondary level in Japan:

The national science standard, curricular objectives and intended contents are published by MEXT in the form of 'course of study'. Science instruction in Japan starts from grade 3. The recent seventh phase of national curriculum reform have made in 2017-18 and have been implemented during 2018-2020 for the lower secondary section (MEXT, 2017a, Kyi and Isozaki, 2023)

The overall goals of lower secondary science curriculum were

i) To make the students interested and curious about natural phenomenon and things.
ii) To understand the natural things and phenomenon through active participation in experiments and by minute observations.
iii) To develop scientific investigation attitude in a purposeful way.
iv) To develop in-depth understanding of knowledge about natural things and phenomena.
v) To develop scientific way of observation and thinking ability.

Three vital aspects of science curricular objectives viz. 'knowledge', 'ways of thinking' and 'attitude' may become helpful for solving current global issues as mentioned by United Nations in their SDG (Shimoda et al., 2021).

In Japan, science is divided into two separate fields at the lower secondary level as 1. Physical science and 2. Biology and earth science.

Curricular objectives of physical science (for grade 8): the students will be able

1) To take part actively in observation and experimentation related to natural things and phenomenon and discover new methods of solving problems through active participation.
2) To acquire skills like analysing, interpreting and expressing the results of experimentation related to natural things and phenomenon.
3) To acquire skills like analysing, interpreting and expressing the results of experimentation related to chemical substances and also realise the utility of chemical substances in daily life.

4) To realise the connections between science and technological innovation through activities and consequently they will improve their scientific way of thinking and develop their extensive view about the natural phenomenon.

Curricular objectives of biology and earth sciences (grade 8):

Curricular objectives of biology and earth sciences are same as that of physical sciences objectives (1), (2) & (3) but for biology the topic will be related to living things and phenomena and for earth sciences the topics will be related to the Earth and the universe. The curriculum of biology and earth sciences will help in developing moral aspects of life and make awareness of sustainable future.

6.3 STEM education perspectives:

The term 'STEM' was first introduced by the United States National Science Foundation in 2001. STEM is a field of combination of four disciplines viz. science, technology, engineering and mathematics. According to UNESCO's observation STEM education is the mandatory component of modern day's competency based curriculum.

IN India, STEM education in school level does not pay attention and not mentioned in the policy documents.

In Japan, the concept of STEM education is very recent and pay significant attention after publishing Science and Technology basic Plan by Japanese government in 2016. After implementation of the plan Government has increased funding for STEM education research and planned to transform secondary and elementary school classrooms as STEM learning conducive. Three purposes of such classrooms were to become familiar with the STEM learning environment, individualized learning of students according to their interest and Information and Communication Technology enabled learning (Kumano, 2022).

In 2017, different provinces of China published the STEM education curriculum standards and guidelines and formally included in K-12 curriculum (Meng et al., 2022). STEM education reform in China has a huge impact and development of rural education (Ma, 2021). Although Chinese students have strong foundation in science subjects but they have deficit in creativity and lack of interest in science in Programme for International Student Assessment (PISA). So, many research scholars were doubtful about the success of science education through STEM model in elementary and secondary schools (Meng et al., 2022).

6.4 Major changes science curriculum: current scenario

6.4.1 Indian context

The latest curriculum reform in India (NCF-2023) was formulated according to the recommendations of NEP-2020 and was published in August 2023. NCF 2023 clearly depicted a 'top-down' hierarchy of how curricular aims leads to learning outcomes (as shown in Figure 2). NCF-SE has articulated the science curriculum in such a way that the students will gain scientific knowledge through Indian rootedness i.e. they will learn the developmental history Indian science. Creativity and innovation got much more priority instead of rote learning approach. Curriculum burden have been reduced and emphasized on hands on activities. Multidisciplinary holistic integrated education approach has been taken and there should the no hard separation between science arts and commerce stream at the secondary phase II.

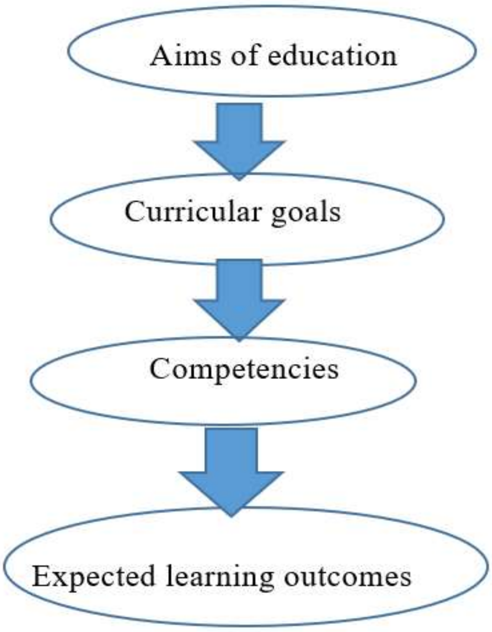

Figure 2: Top-down hierarchy of curricular aims in India (according to NCF-2023)

6.4.2 Chinese context

MOE, China reorganised and included science in the primary school curriculum like developed countries which reduces the gap between pre-school and school science education (MOE, 2001). This change was reported by some media as 'spring of science education' (Zhang & Chen, 2017).

In recent years Chinese curriculum system has emphasized on digitalization after the report published by 20th National Congress of the Communist Party of China (CPC) aiming for promoting digitalized education system. On the basis of CPC's recommendation the central government, local governments and school authorities of China have included information technology (IT) with curriculum and achieved some success. One of the most successful step of integrating IT with curriculum was implementing smart education platform. The unique features of this smart education platform like easy accessibility, sharing and individual development leads to the base of sustainable future through curriculum resources (Luo, 2023). China's eighth curriculum reform first advocated for threefold curriculum controlling system to give more power to develop and operate school based and local contextualized curricula. Again, ninth phase curriculum reform initiated for shifting previous fully centralised curriculum management to decentralised curriculum management system and for this purpose local governments and schools have given more authority for innovative curriculum ideas (Luo, 2023). The curriculum standards 2022 clearly mentioned that the local governments and school authorities may utilise their 14-18% of total teaching hours for extensive practical activities through local and school based curricula. The new curriculum program and curriculum standard 2022 has emphasized on "why to teach", "how should be teaching" and "how teaching can be supported" (MOE, 2022) and after nine years of rigorous practice of new curriculum program China has improved in their curriculum reform significantly (Luo, 2023).

Chinese government had taken initiatives to transform their rote-learning based exam centric education system to students' lifetime holistic development oriented education. For this purpose MOE implemented new curriculum standards with changed teaching learning objectives, curricular framework, improved teaching learning materials and teaching evaluation criteria.

The structure of science courses in high school is shown in the Figure (3) (MOE, 2017). There are three courses in high school science viz. compulsory course, optional course I and optional course II. Compulsory course module is mandatory for all high school students and on the basis of this course module the 'qualification examination' is designed for entry into high school. Optional course module I is designed for the students who are aiming to continue their study in the science field and on the basis of this course module the 'Gaokao' (college entrance examination) is designed. Optional course II is an autonomous course where students can study independently through in-depth learning (Yao and Guo, 2018b)

6.4.3 Japanese context

The latest national curriculum standards in Japan were notified in 2017 and its' proposed implementation timing was from 2020 to 2022. The new curriculum standards were focused on the goal of education, teaching contents and improved pedagogical innovations on the basis of Central Council of Education's report (CCE) (Central Council of Education, 2016). The CCE's report mentioned how the paradigm will be shifted from "teacher's centred teaching content" to "student's centric learning according to their ability and pace". This paradigm shift will leads to in-depth experiential learning linked with their societal workings also improve student's qualities and competencies needed for 21st century learning. Such type of learning would be able to make the learners as lifelong learners (MEXT, 2017-2018).

Japan has transformed their education system from twentieth century education (rote learning based) to twenty first century education for knowledge application (*yutori*) in the last four decades (Yamanaka and Suzuki, 2020).

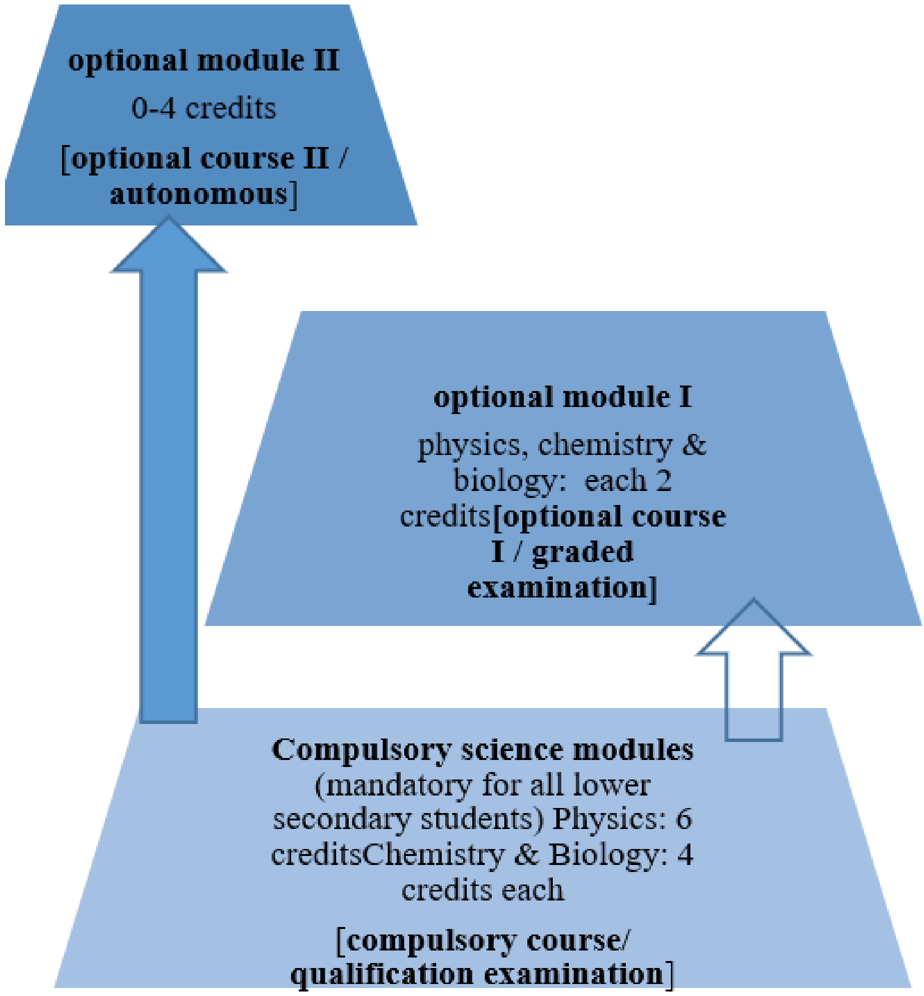

Fig. (3): High school science course structure in China (adapted from MOE, 2017)	India	China	Japan
School education structure	5 years (foundational stage) +3 years (preparatory stage) + 3 years (middle stage) + 4 years (secondary stage phase I & phase II).	6 years (primary) +3 years (lower secondary) + 3 years (upper secondary).	6 years (primary) +3 years (lower secondary) + 3 years (upper secondary).
Frequency of curriculum reform	Less frequent and there is no time period ascertained.	Less frequent and no definite time period ascertained.	Very much frequent(once in every ten years)
Monitoring or supervision of curriculum implementation process	Not so much strict monitoring system like China and no penalty or reward system is evident at school level.	Very much rigorous and there is a provision of reward and penalty system at the school level in the MOE's curriculum standard (MOE, 2022).	Monitoring is systematic but no penalty or reward system is evident in Japan.
Science curriculum program at secondary stage	A compulsory integrated science curriculum is followed at primary, middle and secondary stages.	Most of the schools has followed integrated science curriculum but some schools follow disciplined based science curriculum at the lower secondary stage.	A common compulsory science curriculum program is followed at primary and lower secondary stages.
Curriculum transaction or implementation approach	Top-down administrative approach is followed. Central government and state governments are the supreme authorities and schools has no freedom or flexibility.	Top-down administrative approach nationwide. Schools of different provinces has the power to modify the national curriculum according to their school context. So there is a clear indication of changing top-down approach to bottom-up approach.	Although top-down administrative approach was followed but in the recent curriculum reform bottom-up approach has got much importance.
Curriculum at different levels	National and state level curriculum.	National, provincial and school level curriculum	National and municipality level curriculum.
Students' academic achievements in science different stages of schooling	Portrayed in the National Curriculum Framework for School Education.	Clearly mentioned in the national curriculum standard	Clearly depicted in the national curriculum standard (course of study)

Table (4): Detailed Comparative analysis of various aspects of curriculum reform in India, China and Japan

6.5 Discussion and comparative analysis:

A detailed analysis of curriculum reform in various aspects is tabulated comparatively in Table (4).

6.5.1 Comparison with respect to curriculum objectives:

- ❖ Both China and Japan have grade specific subject wise curriculum goals (OECD, 2020b) including science subjects. India has also stage specific goals for all subjects including science subjects (NCERT, 2023).
- ❖ All the three countries pay much attention for scientific values, attitudes and skills in their curriculum objectives for sustainable future.
- ❖ China and Japan always giving much more importance in their rootedness of their culture and historical national developments in science. In India, according to NEP-2020's recommendation NCF-SE has added significant importance of learning rootedness in India and Indian science knowledge system.
- ❖ Indian science education curriculum goals and competencies leads to mainly learning outcomes. Chinese science curriculum has given greater importance on core competencies which leads to students' holistic development.

6.5.3 Comparison regarding curriculum reform and implementing authorities:

- ❖ Central governments of all the three countries publish their national level curriculum standard.
- ❖ The latest Chinese curriculum reform (ninth) paid much attention for changing completely centralized curriculum management system into decentralized curriculum system. Japanese curriculum reform system is more decentralized compared to China. Indian curriculum reform system is fully centralized in nature.
- ❖ Curriculum reform is much more frequent and systematic in Japan than that in India and China.
- ❖ Japan has transformed their education system (including science education curriculum reform) from twentieth century rote learning base to twenty first century knowledge application based education. China has also transformed their rote learning based education system to students' holistic development oriented education and hence curriculum reform accordingly. NCF-2023 in India make a provision for multidisciplinary integrated education for holistic development through less curriculum content and flexibility in choosing subjects at the secondary level.
- ❖ Recent curriculum reforms of China and Japan indicated that they are shifting their curriculum implantation approach from top-down to bottom-up approach which is aligned with the global trend, but in India bottom-up approach is still neglected.
- ❖ In India, states has the freedom to modify in the curriculum standard but schools has no freedom in this regard. In China provinces as well as schools has the freedom and flexibility for implementing national curriculum standards. In Japan, government of different municipalities has the complete freedom and flexibility in implementing the national curriculum standard.

6.5.4 Comparison of science curriculum at secondary stage:

- ❖ In India, primary through middle stage and secondary stage (phase I) follows integrated science curriculum (physics, chemistry and biology in a composite manner).most of the Chinese schools follow integrated science curriculum (physics, chemistry and biology altogether) at the primary and lower secondary stage but some junior high school follow disciplined based science curriculum at the lower secondary stage. Japan follows integrated science curriculum (physical science, life science, and biological science and earth science altogether) at the primary through lower secondary stages.
- ❖ Both China and Japan have given more importance in physics at the lower secondary stage with compared to chemistry biology or earth science (in Japan) whereas in India integrated science curriculum at the middle and secondary stage contains almost equal percentage of physics, chemistry and biology topics.

6.5.5 Comparison concerning STEM and information and communication technology (ICT) perspective:

- ❖ Both China and Japan have taken the initiative for their STEM specific curriculum reform and have published the curriculum standard accordingly for inclusion in K-12 science curriculum. On the other hand, India did not take such an initiative for inclusion of STEM in the secondary science curriculum.
- ❖ Both China and Japan have allocated huge funding for STEM education at the school level whereas money allocation for Indian school science education is much less compared to the other two Asian countries under consideration.
- ❖ China has emphasized on digitalization of curriculum resources for easy availability and sharing purpose. Japan being the technologically most developed country uses information and technology very successfully in their curriculum reform and curriculum implementation process. Both Chinese and Japanese governments have taken initiative (specifically during and after covid 19 pandemic) to transform their school classrooms digitalized. In India, NEP 2020 also recommended for utilizing ICT for fruitful learning of school children and thereafter NCF-SE has documented the areas where ICT can take a leading role for improving school curriculum including science.

7. Conclusion:

The study investigates several possibilities of curriculum reform, goals and implementation within a curriculum settings of three Asian countries viz. in India, China and Japan and this has furnished a different view of secondary science education. The theoretical framework as well as pedagogical aspects of education system in the three countries clearly indicates the colonial effect of educational philosophy. India, China and Japan all have started their modernized science curriculum reform since three to four decades. China has implemented comprehensive curriculum reform systematically and consequently its' fruitful effects is observed in many areas for the last few decades. Japan has the most systematic and frequent curriculum reform than the other two countries. The last phase of curriculum reform in India made huge provision of changes including structural and curricular framework and if implemented successfully may leads to fulfill 21st century appropriate UN's sustainable development goals. Both Chinese and Japanese curriculum competencies are much more aligned with the OECD's CCM framework. Both Japan and different provinces of China consistently have been performing well securing top rankings in international science competitions like PISA and TIMSS, whereas India participated only once in PISA 2009 and made the worst performances in science with the lowest rankings, and thereafter no initiative was taken to participate in such international competitions. The results of this study may be helpful for policymakers during creating policies for national curricula considering similar indigenous national contexts.

References

1. Bangping, D. (2015). Science education in mainland China. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp.882-889). Springer. https;//doi.org/10.1007/978-94-007-6165-0-530
2. Cai, J. (2014). Searching for evidence of curricular effect on the teaching and learning of mathematics: Some insights from the LieCal project. *Mathematics Education Research Journal, 26(4), 811-831*. https://doi.org/10.1007/s13394-014-0122-y
3. Central Council of Education (2016, December 21), Improvement of National Curriculum Standards for Kindergartens, Elementary Schools, Lower and Upper Secondary Schools, and Schools for Special Needs Education (Recommendation), MEXT. http://www.mext.go.jp/b_menu/ shingi/chukyo /chukyo0/toushin /1380731.htm
4. Cuban, L. (1993). The lure of curricular reform and its pitiful history. *The Phi Delta Kappa, 75*(2), 182-185.
5. Education Commission 1964-1966. (1966). Education and National Development: Report of the EducationCommission 1964-66. New Delhi: Publication Department, National Council of Educational Research and Training.
6. Gericke, N., Hagberg, M., & Jorde, D. (2013). Upper secondary students' understanding of the use of multiple models in biology textbooks–The importance of conceptual variation and incommensurability. *Research in Science Education, 43*(2), 755-780. https://doi.org/10.1007/s11165-012-9288-z
7. Gotwals, A. W., & Alonzo, A. C. (2012). Introduction: Leaping into learning progressions in science. In A. C. Alonzo & A. W. Gotwals (Eds.), *Learning progressions in science* (pp. 3–12).Rotterdam: Sense
8. Isozaki, T., & Pan, S. (2016). Why we study the historyof science education in East Asia: A comparison of the emergence of science education in China and Japan. In *Science education research and practice in East Asia: Trends and perspectives*. East Asian Association for Science Education.
9. Japan Science and Technology Agency (n.d.). What Super Science High School is. https://www.jst.go.jp/cpse/ssh/ssh/public/about.html.
10. Kumano, Y. (2022). Status of STEM/STEAM Learning in Japan: International Perspectives on Preparedness for Society 5.0. In Concepts and Practices of STEM Education in Asia (pp. 63-78). Singapore: Springer Nature Singapore.
11. Kyi & Isozaki (2023). Comparing science curricula in Myanmar and Japan: Objectives and content covered in lower secondary textbooks. *EURASIA Journal of Mathematics, Science and Technology Education,* 19(7). https://doi.org/10.29333/ejmste/13305
12. Lehrer, R., & Schauble, L. (2015). Learning progressions: The whole world is not a stage. *Science Education*, *99*(3), 432–437.
13. Liu, X., & Gong, X., & Wang, F., & sun, R., & Gao, Y., & Zhang, Y., &Zhou, J., & Deng, X. (2017, June). *Anew framework of science and technology innovation education for K-12 in Qingdao, China*. Paper presented at 2017 *ASEE International Forum*, Columbus, Ohio. https://peer.asee.org/29271
14. Luo, S. (2023). The current landscape and future direction of curriculum reform in China. *Future in Educational Research*, 1(1), 5–16. https://doi.org/10.1002/fer3.8
15. Ma, Y. (2021). Reconceptualizing stem education in china as praxis: A curriculum turn. Sustainability (Basel, Switzerland), 13(9), 49-61.
16. McDonald, C. V., & Abd-El-Khalick, F. (2017). Representations of nature of science in school science textbooks. In C. V. McDonald, & F. Abd-El- Khalick (Eds.) *Representations of nature of science in school science textbooks. A global perspective*. (pp. 1- 19). Routledge. https://doi.org/10.4324/9781315650524-1

17. Meng, N., Yang, Y., Zhou, X., & Dong, Y. (2022). STEM Education in Mainland China. In Concepts and Practices of STEM Education in Asia (pp. 43-62). Singapore: Springer Nature Singapore.
18. Ministry of Education (MOE). (2001). The compendium for curriculum reform of basic education (Trial ed.). *The China Education Network Website*. Retrieved August 22, 2023, from: http://www.edu.cn/20010926/3002911.shtml.
19. Ministry of Education (MOE), P. R. China. (2017). *Notice about the issuance of 'Course Plan for Senior High School' and Subjects' Curriculum Standards for Senior High School".* http://www.moe.gov.cn//publicfiles/business/htmlfiles/moe/s8001.html
20. MEXT. (2017a). Course of study for lower secondaryschool science: The curriculum guidance. *Ministry of Education, Culture, Sports, and Technology*. https://www.mext.go.jp/content/20201203- mxt_kyoiku01-100002608_5.pdf
21. Ministry of Education of China (MOE). (2022). *Compulsory education curriculum program and standards* (2022 edition). Beijing Normal University Press. [in Chinese].
22. Ministry of Education, Culture, Sports, Science and Technology (MEXT) (2017–2018, March). *National Curriculum Standard for Lower Secondary School,* http://www.mext.go.jp/component/a_ menu/education/micro_detail/ icsFiles/afieldfile/2019/09/26/1413522_002.pdf
23. NCERT. (2005). *National curriculum framework (NCF-2005) for school education* New Delhi: Publication Department, NCERT, 46-50.
24. NCERT. (2023). *National curriculum framework (NCF-2023) for school education*, New Delhi: Publication Department, NCERT, 213-215.
25. NCERT. (2023). National curriculum framework for school education (NCF-SE, 2023), New Delhi: Publication Department, NCERT, 294-306.
26. NGSS Lead States. (2013). *The next generation science standards: For states, by states*. Washington,D.C.: National Academies Press.
27. OECD. (2016). *Education in China: A snapshot*. https://www.oecd.org/china/Education-in-China-a-snapshot.pdf
28. OECD. (2018). *Education Policy in Japan: Building Bridges Towards 2030*, Reviews of National Policies for Education, OECD Publishing, Paris, pp. 15-17. https://doi.org/10.1787/9789264302402-en
29. OECD. (2020a). *Curriculum reform: A literature review to support effective implementation. Working Paper No. 239*. OECD Publishing. https://www.oecd-ilibrary.org/docserver/efe8a48cen.pdf?expires=1692547949&id=id&accname=guest&checksum=48F23AD353C075FD9EF80EBE5B0CDA35
30. OECD. (2020b). *Curriculum Overload: A Way Forward*, OECD Publishing, Paris, https://doi.org/10.1787/3081ceca-en.
31. People's Daily. (2019). *Zhongguo xuesheng hexin fazhan suyang (Core competencies and values for Chinese students' development).* Retrieved July 28, 2022 from http://edu.people.com.cn/n1/2016/0914/c1053-28714231.html
32. Pramanik, S. (2019). Contemporary mathematics education at secondary level in India, China and USA: A comparative evaluation (Doctoral dissertation). Retrieved from. http://hdl.handle.net/10603/459894
33. Pramanik, S., & Guha, D. (2019). A comparative study on development of secondary mathematics curricula of India and China. In M. Chakrabarti (Ed.), Cognizance: The new vistas of education & psychology, Vol. II (pp. 140-149). Kolkata: Paschimbanga Anchalik Itihas O Loksanskriti Charcha Kendra (PAIOLCK).
34. Research Group of the core competences for Chinese students' development. (2016). *The core competences for Chinese students' development,* Beijing: Beijing NormalUniversity Press.
35. Secondary Education Commission. (1953*). Report of the Secondary Education Commission (1952-1953).* Ministry of Education, Government of India. https://www.educationforallinindia.com/1953%20Secondary_Education_Commission_Report.pdf.
36. Shimoda, K., Morimoto, S., Azuma, T., Ishikawa, K., Isozaki, T., Ito, H., Inagaki, S., Iwaki, K., Okiharu, F., Kajiwara, H., Kamata, M., Kiryu, T., Kubota, Y., Kurita, K., Kurihara, J., Komori, E., Sato, T., Sugawara, T., Takahashi, S., Yamada, T. (2021).Chuugakkou kagaku 1 [Lower secondary school science Grade-1]. Gakkotosho.
37. The State Council. (2019). Guanyu shenhua jiaoyu jiaoxue gaige quanmian tigao yiwu jiaoyu zhiliang de yijian (Guidelines on deepening the reform of education and teaching and comprehensively improving the quality of compulsory education). http://www.gov.cn/zhengce/2019-07/08/content_5407361.htm
38. University Education Commission. (1948-1949). *The Report of the University Education Commission (December 1948 – August 1949).* Ministry of Education, Government of India. http://www.academicsindia.com/Radhakrishnan%20Commission%20Report%20of%201948-49.pdf.
39. Valverde, G. A., Bianchi, L. J., Wolfe, R. G., Schmidt, W.H., & Houang, R. T. (2002). *According to the book: Using TIMSS to investigate the translation of policy into practice through the world of textbooks*. Kluwer.https://doi.org/10.1007/978-94-007-0844-0_8
40. Voogt, J., Niveen, N., & Klopping, S. (2017). *Curriculum Overload: A Literature Study*, unpublished OECD Reference Document.
41. Wang, T. (2019). Competence for students' future: Curriculum change and policy redesign in China.

ECNU Review of Education, *2*(2), 234–245. https://doi.org/10.1177/2096531119850905
42. Yamanaka. S., & Suzuki. K. H. (2020). Japanese education reform towards twenty-first century education. In F. Reimers (Eds.), *Audacious education purposes* (pp. 81-103). Springer. https://doi.org/10.1007/978-3-030-41882-3_4
43. Yao, J.-X., & Guo, Y.-Y. (2018a). Validity evidence for a learning progression of scientific explanation. *Journal of Research in Science Teaching*, *55*(2), 299–317.
44. Yao, J.-X., & Guo, Y.-Y. (2018b): Core competences and scientific literacy:the recent reform of the school science curriculum in China. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2018.1514544
45. Yin, H. (2013). Implementing the national curriculum reform in China: A review of the decade. *Frontiers of Education in China*, *8*(3), 331–359. https://doi.org/10.3868/s110-002-013-0023-3Zhang, Y., & Chen, J. (2017, 22 March). How science education prepare for the ‘spring’ [科学教育如何迎接“春天”]. *Guilin Daily*, p. 3.