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Research Article

Science Teaching Strategies At The Secondary Level In India, Singapore And The USA: A Comparative Study

Anisha Nandy[1*], Dr. Aniruddha Ray[2],

[1*]Research scholar of Department of Education in Swami Vivekananda University, Barrackpore, West Bengal, India, email-id; anishanandy@gmail.com
[2]Prof. of Department of Education in Swami Vivekananda University, Barrackpore, West Bengal, India

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ABSTRACT

To meet the curricular goals of science education effectively and efficiently, proper handling of science curriculum is necessary. It can be effectively carried out by proper science teaching strategies maintained by the science teacher. Science teaching strategies should be maintained from very beginning i.e. lower secondary level when the subject is introduced in school curriculum as separate disciplines. In this study, the science teaching strategies of India, Singapore and the USA has been discussed comparatively. This is a qualitative study with few-country comparison methodology. The authors depend on secondary data collected from Government documents of the three countries, various journal articles, edited books, websites, research thesis etc. to apply document-based analytical approach. It is found that, India has lagged behind than Singapore and the USA in case of applying Information and Communication Technology (ICT) and Science Technology Engineering Mathematics (STEM) classroom more effectively for science teaching at secondary level. Though various attempts for innovative science teaching strategies were made after NCF-2005, but practically all of them were not successful. Activity-based, inquiry-based, blended, student centric teaching strategies are highly solicited for India for better performance in various International tests like, Programme for International Student Assessment (PISA), Science Olympiads etc. Through NEP-2020, India has started to nurture creativity and incorporate critical-thinking skills in science teaching more vividly.

Key words:-science teaching strategies, secondary level, India, Singapore, USA, ICT

Introduction

Science curriculum can be flourished in its full phase through its proper handling by a science teacher. ALI Research Staff (2023) found that science teaching was not 'merely imparting knowledge' but it demanded 'students' critical thinking skills', 'natural curiosity', and 'passion for science' for a lifelong duration. To make these goals successful student-centric teaching strategies were necessary for imparting knowledge. Here the importance of science teaching strategies is arisen. Application of technology in science class room has been found more prominently in case of the USA through its STEM classroom. (NAP, 2013) Singapore being a very small country has incorporated and blended technology in its STEM classroom also at secondary level just like the USA and performed extraordinarily well in PISA; (Teo & Choy, 2021) whereas for India technology has been started to be introduced in science classroom through ICT. (Jamal Uddin & Agarwal, 2020) After NEP-2020, it has been going to be more effective. (NCERT, 2023)
Here the researchers get interests to compare the science teaching strategies of India, Singapore and the USA at secondary level.

Review of literature

Vijayalakshmi (2019) stated that to fulfil the educational objectives in maximum, it is desired to incorporate new methods as well as new techniques in science teaching strategies. In addition to traditional methods like- 'instruction', 'individualised teaching' and 'individualised learning' introduction of ICT was needed in science teaching-learning process as it made the latter more effectively efficient. Although in higher education, many teaching methods were assigned, but only a few of them were in use practically. So, to transfer learning contents from textual mode to visual mode, innovative as well as effective teaching methods were necessary. It would help to open a new paradigm for students' 'active participation', 'perception' and 'cognitive development'.
Jamal Uddin & Agarwal (2020) mentioned about the importance of inculcation of ICT in school science education in India. They also stated the present status of teaching-learning strategies in India with its pros and cons along with recommendations for future improvement.
Tan & Caelon (2023) stated that in Singapore teaching technique was needed to be shifted from 'transmissionist approaches' to 'constructivist approaches'. In the first approach, knowledge was transmitted in a form of fixed set of ideas from dependable sources to students. In the second one, students played a vital role in construction of knowledge. The study focused on optimized learning of students by 'inquiry-based teaching' and it had been found that for better outcomes of the students the method can be adopted situation-wise and problem oriented.
Some student-centered teaching strategies has been depicted as – (ALI Research Staff, 2023)

a) Hands-On Experiments,
b) Connecting real-World,
c) Collaborative learning,
d) Inquiry-based learning,
e) Integrating technology,
f) Differentiated instruction,
g) Project-based Learning

To engage students actively in study and to enhance learners' levels of learning, their motivation is highly needed along with the modern teaching strategies guided by advanced pedagogical paradigms with inclusion of ICT. Therefore, an innovative teaching method in classroom situation is necessary which integrates new teaching methods and strategies. Such a method, described by Vijayalakshmi (2019), could be simplified as-

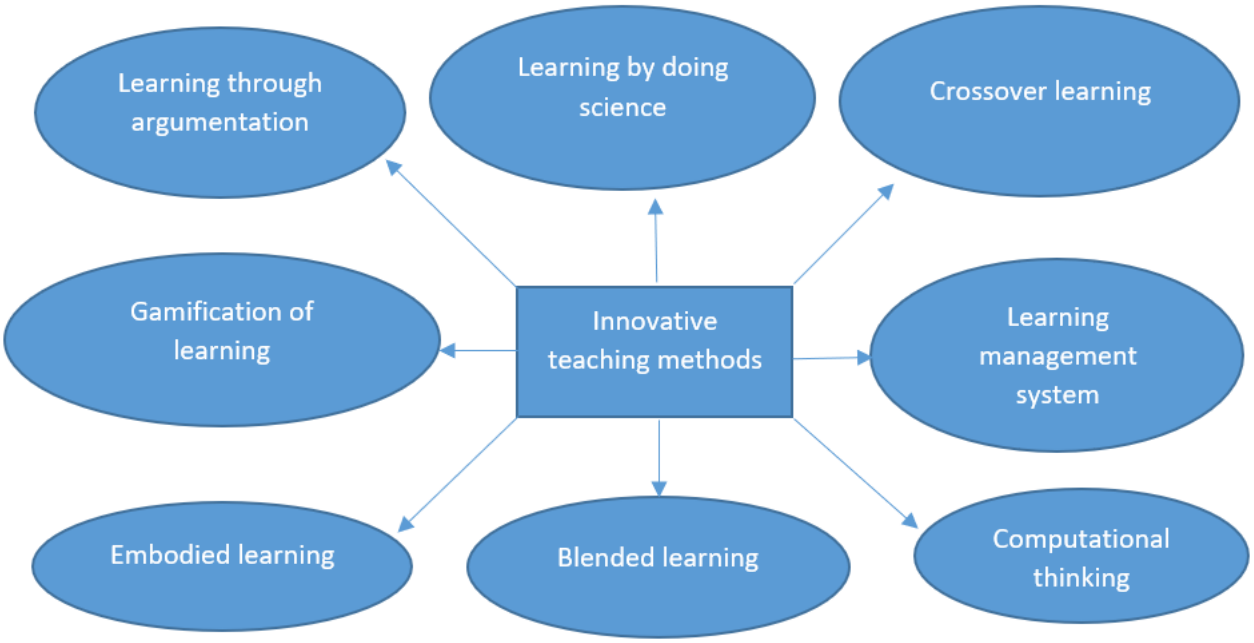

Fig 1: Various strategies included in innovative teaching methods

Research gap

No comparative study has been found to date about the science teaching strategies in India, Singapore and the USA at secondary level. The study has focused on filling that gap.

Objectives

Objectives of this study are-

I. to study the science teaching strategies of India, Singapore and the USA at the secondary level,
II. to compare the science teaching strategies of the three countries.

Methodology

General methodology: Qualitative study,

Methodology: Few-country comparison,
Comparative method: Case-oriented studies, Document analysis, Content analysis
Research materials:
Original government documents, books, edited books, Ph.D. thesis, newspapers, magazines, and peer-reviewed journals.
Data collection process:
Multiple procedures consisting of studying journals (print and online both), books, newspapers, and periodicals have been used.
Data analysis:
The study has employed the current document-based analytical approach. To analyse the collected data historical and sociological strategies have been adopted.

Major findings

Teaching strategies prevailing in India

Teaching techniques of India has been controlled by rules and regulations pertained by various commissions and committee held throughout. At present NCF-2005 has been followed in secondary schools for teaching science. Various councils like- National Council of Educational Research and Training (NCERT), The National Council for Science and Technology Communication (NCSTC), National Council of Science Museums (NCSM) with other Govt. Institutes like- Eklabya, All India Science Teachers' Association (AISTA), Indian Association of Physics Teachers (IAPT) etc. are responsible for conducting science teaching-learning process in India. EDUSAT is used in the wings of open learning. Many private and aided school are equipped with science laboratory, ICT along with libraries. (Jamal Uddin & Agarwal, 2020)

Features of teaching technique according to NCF-2005 (NCERT, 2005)

- Developing science corners,
- Maintaining equitable provisions in case of science learning,
- Providing kits for science experimentation even in rural areas,
- Using of ICT as equaliser between rural and urban areas and as a connector between scientists and the students,
- Discouraging Rote learning,
- Encouraging Inquiry learning,
- Nurturing creativity and inventiveness by emphasising co-curricular and extra-curricular activities,
- Expanding Science Congress, Science and technology fair from district to state to national level gradually,
- Empowering science temperament of young students and teachers not only in India but also in South-Asia.

Modification of teaching technique according to Pedagogic principle in NCFSE-2023 (NCERT, 2023)

Teaching techniques should be in accordance with the following pedagogic principles as mentioned in Table 1.

Table 1: Teaching techniques according to pedagogic principles (NCERT, 2023)

Sl. No.	Pedagogic principles	Teaching techniques
1	To engage science learning students actively with their surroundings	• Stimulating science learning through questioning, making hypothesis, observing, testing and finding evidence, collecting and analysing data, making conclusions and re-questioning in need, • Learning science in classroom, laboratory and field by inquiry, didactic, hands-on activities, discovery method, • providing various experiences for nurturing curiosity.
2	To communicate for sharing ideas as well as observation	• Using extensively scientific vocabulary during teaching instructions for explaining ideas and observations, • Peer as well as collaborative learning.
3	To increase cognitive as well as procedural capacities of students with gradually complex and abstract ideas	• Utilising multiple representations like, mathematical, graphical, diagrammatic, and models on the basis of students' existing knowledge

4	To make linkage between science and other subjects for the holistic and multidisciplinary learning	• Connecting incidents with scientific knowledge not only inside but also outside the classroom, • Making horizontal connections within various subjects.
5	To enable the science learning for the development of certain values, such as collaboration, sensitivity, empathy, equality of opportunities, respect for diversity etc. as mentioned in NEP 2020	• Teaching technique should be in accordance to develop such values.

Recommended pedagogical approaches along with allied teaching techniques in NCFSE-2023 (NCERT, 2023)

The pedagogical approaches described below can be applied across the three settings- the classroom, the field, and the laboratory for learning science through various teaching techniques as described in Table 2.

Table 2: Teaching techniques according to pedagogical approaches (NCERT, 2023)

Sl. No.	Pedagogical approaches	Teaching techniques
1	Hands-on approach	• To design, manipulate and perform experiments using scientific instruments by trial and error method
2	Discovery approach	• To explore the natural world with self-interests and discover their patterns of working, • To draw attention to natural phenomena that students can explore further.
3	Inquiry approach	• To find out solutions of unknown facts by observing, visualising, experimenting, inferring, communicating, and discovering relations by scientific inquiry.
4	Project-centred approach	• To continue science lesson from within the classroom to outside of the classroom during a time period by artefact collecting and explaining inter-connecting different subject areas.
5	Didactic approach	• To explain scientific terms, phenomena, and the historical development of concepts and ideas mainly under teachers' regulations.
6	Demonstration	• To demonstrate the working of certain instruments or outcomes of experimental set-ups to draw the students' attention to relevant concepts for enhancing students' learning experiences.

Teaching strategies prevailing in Singapore

In Singapore, science education curriculum at secondary level is based mainly on three principles (Nandy & Pramanik, 2024) and they are-

- Core Ideas,
- Practices,
- Values, Ethics and Attitudes.

According to the educational structure of Singapore, for both lower secondary (one cohort onwards) and upper secondary (three cohort onwards) the following common teaching strategies are maintained. This is also applicable for Express/ Normal Academic course and Normal Technical course on both lower and upper secondary levels. (MOE, 2021a; MOE, 2021b; MOE, 2023a; MOE, 2023b; MOE, 2023c; MOE, 2023d)

The common strategies for all levels (MOE, 2021a; MOE, 2021b; MOE, 2023a; MOE, 2023b; MOE, 2023c; MOE, 2023d)

Students are inspired to 'inquire' and 'innovate' through learning experiences where they act as 'Inquirers' and teachers act as 'Facilitators'.

➢ Students as Inquirers

To make the students Inquirers three steps are taken and they are-

- Posing questions,
- Involving in discussions related to socio-scientific issues,
- Engaging in problem solving.

These steps are organised by following methods-

- Asking questions,
- Gathering evidences,
- Formulating explanations,

- Connecting the said explanations,
- Justifying the explanations,
- Reflecting in learning,
- Learning with others,
- Learning using different resources,
- Learning in various environments.

(The last three are applicable mainly for lower secondary level.)

➢ Teachers as Facilitators

Teachers can act as facilitators by –

- Providing opportunities to students to question,
- Supporting students in gathering evidences,
- Encouraging students in formulating explanations,
- Encouraging students in applying their knowledge in daily lives,
- Identifying students' learning gaps.

➢ Pedagogic practices in the Singapore Teaching Practice (STP)

The Pedagogic practices in STP comprise of four core teaching processes which make the base for good teaching. It is shown in Fig 2.

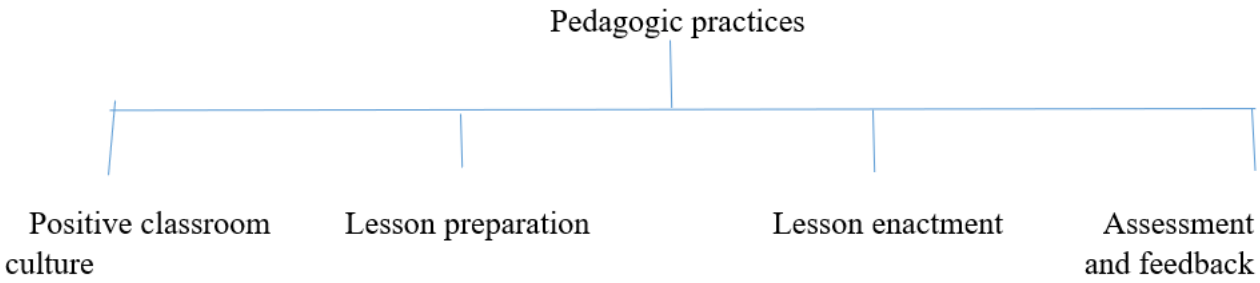

Fig 2: Pedagogic practices in STP

The strategies specific to lower secondary Normal Academic course (MOE, 2021b)

a) Brainstorming,
b) Case Study,
c) Concept Cartoon,
d) Concept Mapping,
e) Cooperative Learning,
f) Demonstration,
g) Field Trip,
h) Games,
i) Investigation,
j) Learning centres,
k) Mind Mapping,
l) Model Building,
m) Problem Solving,
n) Projects,
o) Questioning,
p) Role Play,
q) Stories,
r) Information Technology (IT),
s) National Education (NE),
t) Ethics and Attitudes.

The strategies specific to lower secondary Normal Technical course (MOE, 2021a)

Use of ICT and SLS

Teachers encourage the use of ICT by infusing ICT in teaching tools and resources as ICT is useful for lesson enactment, assessment and feedback. Integration of ICT in teaching strategies increases students' rate of learning. Singapore Student Learning Space (SLS) is one of the MOE's initiatives towards digital learning. It can be customised according to students' needs and can be used in both inside or outside the classroom. It accelerates self-directed learning.

The strategies specific to upper secondary Normal Academic and Normal Technical course (MOE, 2023a; MOE, 2023b; MOE, 2023c; MOE, 2023d)

➢ Blended learning

It is initiated by MOE mainly due to nurture 'self-directed and independent learners' and 'passionate and intrinsically motivated learners'. Integration of home-based learning (HBL) with regular schooling experience is one of its valuable complement. It initiates the habits of life-long learning. It may be of different types as depicted in Fig 3.

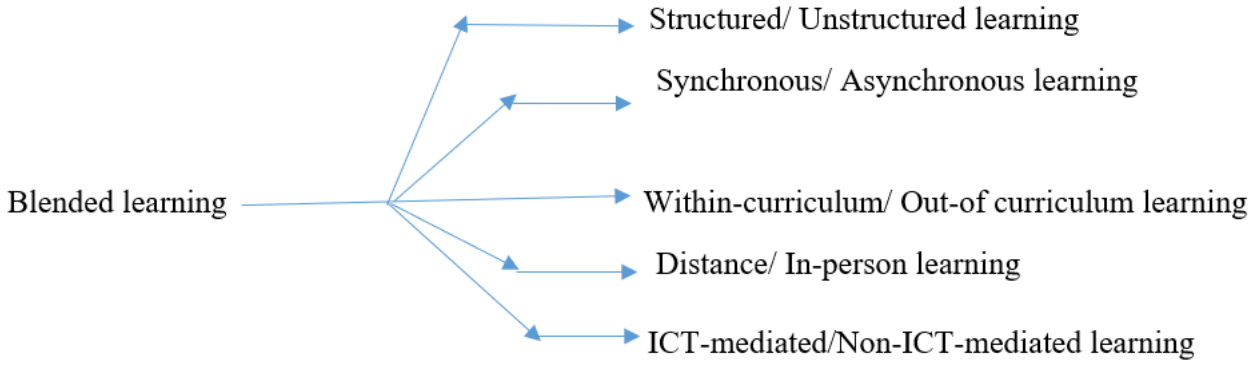

Fig 3: Different types of Blended Learning

➢ Practical work

Practical work helps in students' teaching learning process by-

- Developing science inquiry skills,
- Developing experimental techniques and practical manipulative skills,
- Understanding of the nature of scientific knowledge,
- Enhancing conceptual understanding,
- Cultivating interest in science and in learning science.

➢ Use of ICT

With integration of ICT in teaching learning process, the quality and quantity of science learning increase. Teacher can equip the followings-

- e-pedagogy principles due to lesson design,
- technology due to active learning,
- technology due to assessment and feedback.

➢ Designing STEM learning experiences in science

In science learning, incorporation of STEM design is necessary. It helps the students to be accustomed with globally. Two aspects have to be considered during designing STEM concepts and they are-

- Level of integration,
- Level of application.

Teaching strategies prevailing in the USA

In the USA, the science curriculum follows mainly the three dimensions mentioned in NRC (2012) and they are- (Hirsch & Shaw, 2024)

I. Scientific and engineering practices,
II. Crosscutting concepts,
III. Core ideas in science discipline.

Teaching strategies according to NRC (2012)

The teaching strategies and methods included in the science curriculum according to three dimensions of NRC (2012) can be illustrated through Table 3.

Table 3: Teaching strategies according to three dimensions of NRC (2012) (Hirsch & Shaw, 2024)

Dimensions	Teaching strategies
I. Scientific and engineering practices	• Defining problems through asking questions, • Applying after designing models, • Carrying out an investigation, • Analysing and then interpreting data, • Applying mathematical principles along with computational skills, • Reasoning and then offering solutions, • Evaluating then evidences in a discourse,

	• Obtaining, evaluating and then presenting results coming out of investigations.
I. Crosscutting concepts	• Bridging among various disciplinary boundaries, • Re-occurring the explanatory value of concepts, • Observing patterns of various concepts, • Determining cause and effect relationships, • Introducing scale, ratio and quantity and its relevancy in science curriculum, • Using systems with system models, • Conceptualising structure with its function, • Identifying stability and change.
I. Core ideas in science discipline	• Emphasizing disciplinary core ideas in Physical Science, Life Science, Earth and Space Science, engineering and technology and the application of science, • Teaching the topics mentioned in science curriculum in increasing order of complexity from middle school to secondary school level, • Overviewing the fact that at the end of grade 12, students must develop elaborated and thoughtful knowledge base about the natural phenomena and it's real life applications.

Teaching strategies according to NGSS (2013) (NGSS, 2013)

To make 'equitable learning opportunities' to all non-dominant students' groups three themes are to be maintained and they are-

1) To value and respect all the experiences of students inclusive of their backgrounds,
2) To articulate students' background knowledge with disciplinary knowledge,
3) To offer adequate school sources to give a strong support to students' learning.

These themes are executed through three domains of teaching strategies and they are-

I. Effective classroom strategies,
II. Home and community connections to school science,
III. School resources for science instruction.

These three main domains of teaching strategies can be divided in various teaching techniques depending specified groups/ fields. This is described in Table 4.

Table 4: Teaching strategies and teaching techniques according to the allied specified groups/ fields

Teaching strategies	Specified groups/ fields	Teaching techniques
Effective classroom strategies	Students from economically disadvantaged groups	• Connecting science education according to students' sense, • Applying students' funds of knowledge, • Utilising project-based learning, • Supplying adequate school resources and funds for instructions.
	Students coming from major racial and ethnic background	• Providing pedagogy with cultural relevancy, • Involving community including social activism, • Representing multimodal experiences in multiple way, • Including role models and mentors coming from similar racial or ethnic backgrounds in school support systems.
	Students having disabilities	• Providing differentiated instruction, • Making universal design for learning.
	Students having limited English proficiency	• Having literacy strategies applicable to all students, • Supporting language strategies to English Language Learners (ELLs), • Providing discourse strategies for ELLs, • Supporting home language, • Connecting with home culture.
	Girls	• Motivating girls' children in science studies and science achievements, • Emphasising successful contribution of females in science curriculum,

		• Involving girls through various organisational structures like, after-school clubs, summer camps etc.
	Students involved in alternative education programs	• Providing after-school opportunities in structured format, • Outreaching to their family, • Training of life skills, • Providing learning environment which is safe, • Providing academic support which is individualised in nature.
	Gifted and talented students	• Providing fast pacing, • Providing challenges of different levels, • Motivating to be self-directed, • Grouping strategically.
Home and community connections to school science	Involvement of parents in school science	• Highlighting the academic achievements of siblings and peers as role models, • Assigning homework and interacting with parents, • Involving parents in science-related field trips, • Organising science camp reflecting the parents' values.
	Engagement of students in school science in community contexts	• Engaging students in outdoor explorations, • Making analysis of the local natural resources, • Capitalising the community resources and funds of knowledge, • Providing 'place-based' science education with culturally relevant pedagogy.
	Learning of science in informal environments	• Providing informal environments for science learning like, museums, nature centres, zoos, community gardens etc., • Concerning interests of particular cultural groups while providing informal environments, • Concerning cultural and language practices while framing informal environments for them.
School resources for science instruction	Material resources	• Having compatibility and synergy between instructional times (material resources) allotted for science with other basic subjects like, English Language, Mathematics, Arts.
	Human capital	• Providing most effective teachers specially to non-dominant groups due to overcoming achievement gaps, • Making students able to connect science with theirs home and community, • Maintaining continuity of the learning progressions for highly mobile and immigrant students.
	Social capital	• Collaborating among teachers of different specialisations and subject areas irrespective of traditional collaborations, • Collaborating in all levels of schools from teachers to administrators, counsellors etc.

Comparative analysis

1. In India, science teaching strategies has been following some traditional concepts of teaching. They are generalised for all. No individualised and customised teaching techniques are used. All the students in a class experience the same teaching techniques whether they are interested or not. In the USA, after NGSS, science students are taught not only according to their interests and aspirations, but also to their cultural and social levels. Students are divided in various groups and then they are taught according to their specific group's criteria. In Singapore, students are taught science according to their interests and motivation in different types of secondary courses prevailing in school education structure.
2. In India, science is taught as a composite subject up to class 10 (mainly for central board); disciplinary subjects are introduced in class 11. With the introduction of NEP 2020, choice-based system in science subject has been proposed to be introduced from grade 9 onwards. In Singapore, there is carnival of options for students in science stream. They have their freedom to choose their own subjects and course as per their marks and interests from lower secondary i.e. grade 7 onwards. In the USA, students also get options for their subject-choice which is comparatively less than that of in Singapore.
3. In India and Singapore, al, the teaching strategies are assigned and developed by Ministry of Education of that country. In the USA, the same decisions are taken by district and state boards and federal governments.

4. Concept of STEM classroom has been initiated in the USA first, then it is incorporated and fully flourished in Singapore. Whereas in India, it is yet to be introduced.
5. Use of ICT is in full fledge in Singapore and the USA; whereas in India though incorporation of ICT in science subjects has been started after NCF-2005, but it has got a new paradigm after NEP 2020.
6. Using blended mode in teaching is praiseworthy for Singapore. India has already opened its wing in blended teaching, but it takes time to be flourished in its full form. In the USA, blended mode of teaching is very successfully running along with offline teaching.
7. Incorporation of engineering and crosscutting concepts in science teaching is maximum in the USA and then in Singapore; whereas in India it has been emphasised in NCFSE-2023.
8. Inquiry teaching has been observed in Singapore most and then in the USA. With NCFSE-2023 India has stepped forward in that.
9. Teaching science through hands-on activities and practical work in laboratory as well as in field is maximum for Singapore and the USA from grade 7 and 6 respectively. In India it is mainly observed from class 11. Although, in India 'learning by doing' concept is followed from class 6 onwards by various project and field trips, but practically after NCFSE-2023 it is proposed to be started wholeheartedly from grade 9 onwards,
10. School as well as community resources has played a vital role in science teaching in case of the USA; whereas in Singapore school resources are more important than the community resources for science teaching. In India, school resources are limited and restricted to the schools of urban area mainly,
11. Science teaching is carried out following crosscutting concepts in an inter-disciplinary way most in the USA and then in Singapore; whereas in India it is proposed vividly in NCFSE- 2023.

Conclusion

Within India, Singapore and the USA, though India has started its journey in Science Olympiads with comparatively lagged ranking just like in Mathematics Olympiad (Pramanik, S., 2019), but the country has proved itself more improved and developed year by year, not only with its hard effort, but also with its strong determination and will power. The science curriculum and its manifestation plays a vital role in this regard. Without well organised and well-structured teaching strategies, this manifestation can't be possible. Here the necessity of good and organised teaching strategies arises. Singapore and the USA has applied effectively more advanced, technology-based, student-centric and above all practical-based teaching strategies in science. In India, science teaching strategies also follow the above four features but not vividly and effectively. After NCFSE-2023, India has stepped forward to fill up the gap.

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