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A Comparative Analysis of Secondary Science Teacher Professional Development in India, Singapore, and the USA

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Abstract:

The study compares the professional development of the science teachers at the secondary school level in India, Singapore, and the USA. It follows a qualitative method pursuing document-based analysis. The comparison reveals that for India, secondary science teachers' professional development is generally centred on some theoretical knowledge including some routine-based practical implications. For Singapore, the country follows reform-type and school-based professional development, followed by proper mentoring system, research publication, and ranking and promotion system. In the USA, professional development follows inquiry teaching in astudent-friendly learning environmentenvisioning core ideas, practices, and coherence through various teaching shifts mainly after Next Generation Science Standards (NGSS).

Keywords: *Professional Development, Teacher Education, Science Teaching, Science Teacher, School Science Education.*

Introduction:

Teacher is the main ringleader amidst the dynamism of the whole education system. To attain the international goal of "Education for All" (UNESCO, 1990), it is very much needed to educate the teachers first who build and develop the next generations of citizens of our country. India with the highest population in the world (Worldometer, 2025) has lagged behind in various international tests like- Trends in International Mathematics and Science Study (TIMSS), Programme for International Student Assessment (PISA),etc. (OECD,2014). Singapore with a muchsmaller population and capitalizing human beings (Gopinathan, 2012) as its only natural sources has set its result with high benchmarking from the very first year of participation. The performance of the USA with the third highest population in the world has been praiseworthy always and exists at almost the topmost level. TIMSS, PISA, etc. are the international tests where the trends and performances of primary and secondary level students in Mathematics and Science have been compared with each other for the participating countries. In the 21st century, science is necessarily a way of progression and advancement of society. Therefore, for the empowerment of our society, the direction of science education is essential and here the role of a science teacher as the director is needless to

mention. Teacher's Professional Development(PD) affects the education system and learner's developmental outcomes directly, so many countries put forwardteacher-training programs of both pre-service and in-service teachers, (OECD, 2018). Henceforth, the necessity of a sound teachers' education program and its continuing PD has been arisen. Singapore has prepared a 'knowledge-based economy' with a skilled workforce not only with the help of advanced science-curriculum, but also, they equip their teachers with various professional competencies to make it effective in all ways. Whereas in the case of India, teacher education along with its PD has yet to be improved and improvised so that it can be helpful for reflective learning of science students mainly at the secondary level. The USA has stepped forward to make their science teachers accustomed withNext Generation Science Standards (NGSS) linking with Common Core State Standards (CCSS) (Pramanik, 2019).Therefore, the PD of the country focused on 'inquiry-based learning' concerning science teachers' particular PD needs.

Here the researchers areinterestedin studying the teacher education and PD of science teachers at the secondary level in India, Singapore, and the USA comparatively.

Literature review

A comparative study especially in education and PD provides unique insights that are valuable for theory, policy, and practice. Guha and Pramanik (2019) conducted a comparative analysis of the underlying philosophies guiding mathematics education in China and India dealing with core questions of mathematics education.In the same study, Guha and Pramanik (2019discussed various philosophical schools that shaped mathematics education, including both traditional and contemporary viewpoints found in India and China. Pramanik and Guha (2019a) presented a comparative study on development of secondary mathematics curricula of India and China. Nandy and Pramanik (2024) examined and compared school science curricula in India and Singapore through qualitative analysis and a comparative framework, reflecting systemic contrasts and reform efforts. Pramanik and Guha (2019b) compared mathematics textbooks of secondary level of National Council of Educational Research and Training (NCERT) and West Bengal Board of Secondary Education (WBBSE) based on certain features of textbook. Ghosh and Pramanik (2024) presented valuable insights through their comparative study of science education frameworks in India and China, reflecting similarities and contextual differences. Pramanik and Guha (2019c) offered a comparative analysis of the performance levels of China, the USA, and India in the International Mathematics Olympiad, reflecting the current scenario.Nandy and Pramanik. (2025) presented a systematic comparison of secondary-level science Olympiad programs in India, Singapore, and the USA.Pramanik and Guha (2018) examined the key practices in the PD of secondary mathematics teachers in China and India, and offered a comparative analysis of the systems in both countries. The study (Pramanik & Guha, 2018) revealed that in China, PD is supported by well-established structures, namely, a promotion system and a strong culture of teaching research conducted by the teachers. In contrast, Pramanik and Guha (2018) found that India lags behind China with respect to a structured promotion system and collaborative teaching practices and research dealing with teaching. So, comparative studies reflect strengths and weaknesses while promoting synergistic knowledge integration. In education, comparative studies ensure systems remain inclusive, relevant, and forward-thinking. In PD, comparative studies empowerhuman beings and institutions/organizations to adapt, compete, and lead in a fast-evolving world.

The education system consists of three main components- students, teachers, and the curriculum (Segall and Wilson, 2004). Although all the components are important, the quality of education mainly depends on its implementer, that is, the Teachers, (Kayange&Miska, 2016). A teacher deals with multilingual, diversified students with different socio-emotional and cognitive levels. These aspiration levels of students are ever-changing accompanying globalization into a 21st century world. Thus, teacher and teacher education get

importance for ‘global citizenship education’, ‘peace education’, ‘education for sustainable development’ irrespective of ‘international and inter-cultural understandings’ (MHRD, 2020).

PD of teachers is not a certain event, but a continuous process. Like all professions, in teacher ship, there must be some standards of behaviour that differentiates the teachers from others clearly.

Teacher’s PD can be described as “the body of systematic activities to prepare teachers for their job, including initial training, induction courses, in-service training and continuous professional development within school settings” (OECD, 2010).

Selvaraj et al. (2015) showed in their research article that PD programs for teachers had been essential for balancing with the ever-changingworld, which had, not be satisfied by pre-service education alone. Here, three dimensions of the classroom environment were mentioned- physical, human, and social, which could be nurtured through ‘Classroom Management’ to attain the goal of learning. As a result of effective PD of teachers, functional literacy and numeracy at the primary level have been improved which resulted in better learning of science and mathematics in India.Kaushal (2017) stated in her paper that PD of teachers was directly involved with the quality of education,especially in the higher education sector in India. She mentioned the teachers to be made and the skills acquired by them as the tricks of this education-trade.

Science Teachers have to cater to different roles and use different strategies to satisfy their learners. Thus, sometimes they may appear as learners’ care-giving parents and sometimes as ‘demanding taskmaster’ (Barnett &Hodson, 2001). Therefore, the PD of a science teacher is a crucial study.

Monika and Lal (2021) studied on teaching orientation of two science teachers’ practices in western India and concluded that in spite of many limitations, the trends of science teachers inclined towards the goal of NCF(NCERT 2005), but their classroom practices did not follow that. Their teaching was mostly quantitative rather than qualitative to summit the various teaching goals and restrictions in different national, cultural, and contextual aspects. They mostly followed a more ‘didactic approach’ (i.e., teacher-guided) than inquiry-based learning (i.e., student-driven).

India would learn from the educational reform National Research Council (NRC) and National Science Education Standard (NSES) under National Research Framework of the USA and should apply it to the secondary science teacher teaching system. (NRC, 2000) A glimpse of it was shown through NCF 2000 (NCERT, 2000) and NCF 2005 (NCERT, 2005). Nargund-Joshi (2012) showed in her dissertations that, in India after NCF 2005, most of the science teachers were aligned with the reform. However, they were sometimes retarded due to a lack of ‘pedagogical content knowledge’, ‘knowledge of assessment’, and ‘constructivist instructional strategies’. ‘Several contextual factors’ obstructed their orientations like- ‘limited resources’, ‘large class sizes’, ‘cultural testing pressures’, and ‘limited accessibility to PD’. Besides these, science teaching in India was hampered due to ‘diversity in science classroom’ thus proclaiming the need for activity-oriented textbooks that can be used in general (Koul, 2019).

Barnett and Hodson (2001) found thatscience teachers used generally four types of knowledge while practicing in the classroom, and they were ‘academic and research knowledge’, pedagogical content knowledge, ‘professional knowledge’, and ‘classroom knowledge’. Amongst them pedagogical content knowledge model can be used as a ‘simple and rapid, yet effective and efficient way’ to assess the teachers’ knowledge and skills in their teaching. Through it, a teacher could ascertain the cognitive map of a learner, validate the necessity of a trained teacher over a novice teacher, and justify the PD of a science teacher.

Fischer et al. (2012) found that the estimation of the quality of a lesson (like- science) is inalienable with professional activities of teachers in a classroom situation and results in students’ learning outcomes at

cognitive and emotional levels. The authors mentioned the relationship between three paradigms on which teachers' professional knowledge depended and they were:

a. The Teacher Personality Paradigm,

b. The Process-Product Paradigm,

c. The Expert Paradigm.

The authors mentioned that three components of teachers' professional knowledge were mandatory for science teaching teachers and they were

i. Content Knowledge (CK),

ii. Pedagogical Content Knowledge (PCK),

iii. Pedagogical Knowledge (PK).

Luft & Hewson (2014) stated that with a new vision of learner-centric instruction and new curricular reform in science, a major paradigm shift had been required for science teachers' PD for accelerating learners' outcomes in science. To solve it resources for systematic reform had been required. Systematic initiatives had been taken by the American govt. to strengthen science teachers' PD, funded by the National Science Foundation (NSF)', in which a considerable amount had been allotted for science teachers' PD. Empowering with 'No Child Left Behind Act' (2001)most of the states in the USA had operated proficiency tests by themselves for judging the quality of schools and teachers (Pramanik, 2019). They had been inspired through the country's performance in international tests like – TIMSS, PISA etc. (United States, n.d.).

Wilson (2013) showed that in the USA, after Next Generation Science Standards (NGSS), a massive revolution of PD for all science teachers had been needed due to substantial changes in 'teacher knowledge' and 'teacher practice' as well as students' science achievement. However, due to 'complexity' arisen in the'UWS educational system' the reform had been interrupted.

As research shows, the success of Singapore's education system has been embedded in three independent levels:

i. Macro level (factors covering socio-cultural as well as economic-political),

ii. Organizational level (prioritizing quality of concerning schools, associated teachers and corresponding curriculum, etc.),

iii. Family level (style of parenting including socialization).(Hairon&Dimmock, 2011; Tan &Dimmock, 2014)

Tan and Wong (2007) found that in Singapore Teacher Education was carried out entirely by the National Institute of Education (NIE) and the Ministry of Education (MOE). To teach in a secondary school, the trainee must have an undergraduate degree in a fixed discipline. But, in a single subject, the teacher would have to teach every chapter. All candidates had to go to NIE for training. MOE increased the number of graduate teachers in its workforce. 'underqualified' and 'out-of-field teaching' in Singapore were not found, because MOE controlled the 'surpluses' and 'shortages' of teachers centrally. Thus, Singapore had a 'well-qualified teaching force'.

Tan (2018) showed in his article that, the secondary science students of Singapore did extraordinarily well in international tests like- PISA and TIMSS consistently. The journey of a science teacher from pre-service teacher education to continuing PD is made possible through many Govt. steps and innovations. MOE along with NIE controlled everything in teacher education and PD of science teachers from recruitment to selection and then appointment to PD course. Thus, the author claimed Singapore's PD as 'quality PD'. He described the whereabouts of science teacher education in his article. Tonga et al. (2019) found that quality of teaching is the primary step for students' success. In comparison to the other (here 5) PISA achiever countries, Singapore ranked high in PISA due to its profound teacher education program and on-going in-service training for science teachers.

Bautista et al. (2015) mentioned about three main institutions providing PD in Singapore. They are-

I. The National Institute of Education (NIE),

II. The Academy of Singapore Teachers (AST) with six Centres of Excellence and

III. Schools.

Teachers on their own needs, as well as schools' needs, participated in 'one hundred voluntary hours of PD per year' through different courses like- 'formal/ structured' or 'informal/ reform-based initiatives' (e.g.,'action research', 'lesson study' etc.). Options were provided to teachers to choose from 'different levels of expertise and career paths'. Most of the PD program was 'subject-specific' which helped in teachers' 'networked learning', 'collaborative and collegial sharing'. In Singapore, all schools have to become Professional Learning Communities (PLC) as per the mandate provided by MOE. The authors claimed this PD model as aspiring with high quality with respect to international standards.

Gorski (2009) studied the 'multicultural teacher education (MTE) courses' that prevailed in the USA. It was found that in the USA, the teachers were trained to be efficient in pragmatic and personal skills, but not in multicultural education like 'critical consciousness' and 'educational equity'. A 'five-layer typology' was suggested for MTE.

According to the Professional Development Programs (2015), the PD of science teachers in the USA was formed and provided through many offline and online programs. These had its effects on teacher knowledge, teacher practice, and 'student learning'. Through PD, science teachers were provided new opportunities that helped them to reflect and practice new science instructional methods and strategies for the betterment and advancement of learners' thinking and achievement. Although online activities were very famous, they needed more research and practice to be cherished.

Yoon et al. (2020) found that in the USA, PD of science teachers through online mode especiallyvia MOOC platform had succeeded for K-12 teachers. It could also satisfy the science teachers through their intentional 'collaborative learning and participation'. Thus, it could build 'networked teacher PD communities in asynchronous online PD platform'.

Christian et al. (2021) found that being forced by NGSS to implement engineering practice in traditional secondary STEM classroom, the secondary science teaching PD need to be more research-oriented. To inculcate 'engineering knowledge and fields' properly into secondary classrooms, the education of science teachers was needed first on 'engineering pathways' so that they can apply it successfully. Teachers participated in an 'engineering education workshop' for secondary STEM classes, and a part of their 200-hour PD program.

Covitt et al. (2024) analysed the instructional practices of six middle school and high school science teachers in the USA and concluded that the six teachers differed only fromeach other in the successful support of students' three-dimensional learning. With the students of lower learning, they applied 'activity-based teaching', whereas for higher learning students' 'scientific sense making' and 'cognitive apprenticeship' was applied. The study focused on the balance made by the teachers between 'local and standards-based successes'.

In India, INSET programs had been operated previously. This was mainly based on 'transmission-oriented model' where teachers received expert knowledge and played the passive role in rigid conventional arrangements of institutional training with less contribution in inquiry-based and reflective-teaching practices. Compared to 'Career development' and 'Staff development' in in-service training, Continuous Professional Development (CPD) is more effective as it involves systematic growth and development with regular intervals in the teaching profession in a long way (Villeges-Reimers, 2003). Depending mainly on the National Achievement Survey (2017), the CPD for in-service teachers appeared as an emerging issue under NEP 2020 in India, which has been proposed mainly to make the teachers prepared as reflective practitioners.

Research Gap

No comparative study has been found to date about the PD of school science teachers in India, Singapore and the USA for the secondary level. The study has focused on filling that gap.

Objectives

Objectives of this study are-

I. to study the PD for science teachers of India, Singapore and the USA atthe secondary level with contemporary change,

II. to compare the science teachers' PD 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

Recent Scenario of Teacher Education and PD in India:

Teacher Education Program (TEP) is not a discrete way. It is a continuous process starting from pre-service teacher education to in-service teacher education or PD(Bhatia & Goel, n.d.).

The in-service teacher education in India has been modifiedalong with pre-service teacher education with the enhancement of the teacher education program of duration from one to two years of duration as per NCTE Regulations (NCTE, 2014).

Qualifications required to be a secondary school science teacher:

a. Graduate / Post Graduate (PG) degree in Physics, Chemistry and Biology (including various intra-disciplines in Biology) as a combination/ as a separate subject discipline (i.e.- Honours and Masters) from any recognized university having at least fifty % marks in either Graduation or PG (or its equivalent),

b. Bachelor of Education (B.Ed.) degree obtained from an NCTE recognized institution of two years of duration.

Teacher Eligibility Test (TET) certificate with a graduation degree is necessary for a candidate who wants to be an upper primary teacher.

There is no license certificate system in the case of the teacher education system (Pramanik & Guha, 2018; Pramanik, 2019) in India.

According to NEP 2020, four years of undergraduate (UG)B.Sc. degree has been introduced by UGC, where students can complete a UG degree in three years or a UG Honours degree in four years(MHRD, 2020).

Characteristics of Teacher Education in India:

a) Aim:

In India, teacher education is 'to make it more context-specific, responsive and dynamic with regard to meet the particular needs of India' (Bhatia et. al., n.d.).

b) Brief outline of course structure:

After the NCTE Regulations (2014), the NCERT has revised the existing curriculum and organized it into three categories (NCTE, 2014)

i. Perspectives in Education- (emphasis on Health and Physical Education, Inclusive Education),

ii. Curricular and Pedagogic Studies- (subject knowledge and the related pedagogic Dimension divided into two parts through different subject-areas of secondary subjects- Biological Science/ Physical Science/ Mathematics)

iii. Engagement with the field

- positive engagement with school, children, and society,
- School internship,

- Courses on Enhancing Professional Capacities mainly in using Information and Communication Technology (ICT) (Department of Teacher Education, 2016).

Teacher Education in NEP 2020:

To maintain the 21st century competencies, 'Pandit Madan Mohan Malviya National Mission on Teacher and Teaching' has proposed a four-year Integrated Teacher Education Program (ITEP), to be introduced under NEP 2020. It aims for teacher preparation as per four stages of the new school structure (i.e., 5+3+3+4) enclosing Indian values, ethics, languages, knowledges, etc.(NCTE, 2021)

Characteristics of PD in India:

SamagraShikha (2018-19):

It is an integrated scheme of the Government of India (GOI) covering the entire level of the school education system from preschool to class twelve. It is in accordance with the Sustainable Development Goal for Education (SDG-4) (UNESCO, 2015) which intends to cover the gap between RTE Act 2009 and NEP 2020.

One of its major objectives is to strengthen and upgrade SCERT/SIEs and DIETs as nodal agencies for teacher training. Many provisions are provided for teacher education programs, institutes, and teacher educators. According to it,an annual calendar, for in-service training for the teachers of the secondary section and senior secondary section, has been developed in 'SCERTs and DIETs' (DSEL, 2021).

NISHTHA:

'National Initiative for School Heads' and Teachers' Holistic Advancement' (NISHTHA) is a flagship program of MHRD under the scheme SamagraShikha where all the teachers whether of Government and private sectors irrespective of their recruiting boards and school types (i.e., CBSE, ICSE, state boards etc.) are involved in PD program (Suter, 2022).

- **NISHTHA Offline:**

NISTHA in offline (i.e., face-to-face) mode was first launched on August 2019 which reduces the cascading effect of training at the elementary level. The training at state level for State Resource Groups (SRGs) have been completed for thirty-three states/ UTs in offline mode and only Andhra Pradesh in online mode due to the pandemic. Two states West Bengal and Kerala has yet to take the training(Suter, 2022).

- **NISHTHA Online:**

Due to the COVID-19 pandemic, its pace has been interrupted. Then NISHTHA Online has been first introduced in 2020 to complete the flagship mission through digital platform like DIKSHA portal which can be conceptualized as 'One Nation One Portal', which is in co-ordination with NCERT(NISHTHA Online, 2019).

NISHTHA 2.0:

Among three versions of NISHTHA Online, NISHTHA 2.0 is assigned for secondary level maintaining the link with the elementary level and forming capacity building for secondary level teachers and school heads. It covers the special care for adolescent students from class nine to twelve balancing between the visions of '50 hour CPD' and the 'Foundational Literacy and Numeracy (FLN) Mission' of NEP 2020 (NISHTHA Online, 2021).

- **Objectives:**

Teachers are trained-

i. To become the first-levelcounsellors of students irrespective of their social, emotional and psychological needs,

ii. To utilize Art-based learning for cultivating creativity and curiosity among students,

iii. To construct and amplify the 'personal-social qualities of students' due to their holistic development.

- **Brief outline of course structure:**

The latest version of the course is DIKSHA 4.0. Secondary teachers can complete this course through videos [like- Interactive Voice Response System (IVRS)], text-modules, interactive activities live sessions, etc. delivered by National LevelResourcePersons on DTH SWAYAM Prabha TV Channel.

NISTHA comprises of following course outline covering three concerns, which should be completed by secondary teachers with their own choices, needs and flexibility.

a) Generic concern: There are twelve generic courses with each of three to fourhours' duration- all have to be completed.

b) Pedagogic concern: There are seven pedagogical courses with each of twenty-four to twenty-five hours' duration. Anyone of the courses has to be completed from seven subject areas in which secondary science teachers have to choose a science subject. Various strategies for improvement of classroom practice through Art-based, Toy-based and ICT based learnings are trained.

c) Systematic concern: Encouraging systematic concerns towards 'school leadership concept', 'vocational education' and 'school initiatives and community engagement'.

- **Assessment and Certificate:**

After completion of each generic (total twelve), one pedagogic and courses of systematic concern, the teacher will be certified on scoring a minimum seventy %, with hundred % progress througha maximum of three attempts for each course.

The certificates can be downloaded from the website after online assessments.

- **Other initiatives of MOE:**

a) Promotion of ICT in PD programs has been discussed in portals like SAKSHAT,

b) 'Professional Development Networking' through E-conferences with webinars,

c) Massive Open Online Courses (MOOC) as a new platform for online PD program in a collaborative as well as co-operative manner.

d) Open education resources and NROER have informed about new input of knowledge and skills to improve the learners' learning outcome.

CPD and NEP 2020:

Through CPD,a teacher can make himself eligible to face the ever-changing challenges that arisen in the way of his teaching continuously(Singh & Gupta, 2021).

In India, the term CPD was first used in the National Curriculum Framework for Teacher Education (NCFTE) (NCTE,2009) instead of In-Service Teacher Education (INSTE). Then, INSTE and CPD are used alternatively in NCFTE (2009) and Justice Varma Commission (2012) (MHRD, 2012).INSTE focuses on the improvement of particular teaching skills and/ or knowledge that a teacher needs for his upgradation of teaching, whereas CPD refers to the holistic development of a teacher irrespective of his professionaland personal attitudes for the sake of improvement and wholesome development of the entire learning process (Earley&Bubb, 2004).

Through CPD, the way concerning teachers' PD has been changed from finding out and repairing teachers' personal deficiencies to making teachers responsible and reflective of their own abilities and development (Singh & Gupta, 2021).

NEP 2020 has proposed a knowledge-based society focusing on the development of teachers' own PD depending on their self-interest. It is expected that every teacher will participate in a fifty-hour CPD per year led by their own interest, which involves new approaches to pedagogies (MHRD, 2020).

Designing CPD as per NEP 2020:

- **Nature of CPD:**

It comprises of two modes-

i. In the Institutional approach, face-to-face mode is preferred involving a participative manner and hands-on experience to update teachers' knowledge, skills along desired competencies.

ii. In the Flexible or Cafeteria approach, the blended mode is followed through online and ODL versions depending on teachers' choice of selecting modules as per their professional needs to complete fifty hours of CPD annually as an outcome of their attitudinal change to fulfil 21st century competencies (Suter, 2022).

- **Relevant concerns:**

As teachers are at the centre of educational reform after NEP 2020, the CPD plays a crucial role in making them useful for local contexts as well as national concerns.

Relevant concerns for CPD are-

i. Generic concerns for PD of teachers,

ii. Subject-specific pedagogical concern,

iii. Systematic concerns regarding school community.

- **Some features:**

a) Module development as per the format of NISHTHA/ DIKSHA,

b) Digital Repository of Resource Persons to be maintained,

c) Annual CPD Calendar to be prepared and followed,

d) Continuous assessment of face-to-face and online mode in CPD and certification after completion of each step,

e) Financial supports tom both institutions and candidates wherever needed to be provided,

f) E-portfolio for each teacher has to be maintained (Suter, 2022).

Recent Scenario of Teacher Education and PD in Singapore:

The whole education system of Singapore is controlled centrally by Ministry of Education (MOE) which directly recruits employs all primary, secondary, and junior college teachers (Tan, 2018) taking various strategies for different purposes like- recruitment, necessary compensation of school teachers at the secondary level. Although, Independent Schools have the freedom 'to hire and fire' their own teachers (Tan & Wong, 2007).

Qualifications (See Fig.1) required to become a secondary school science teacher:

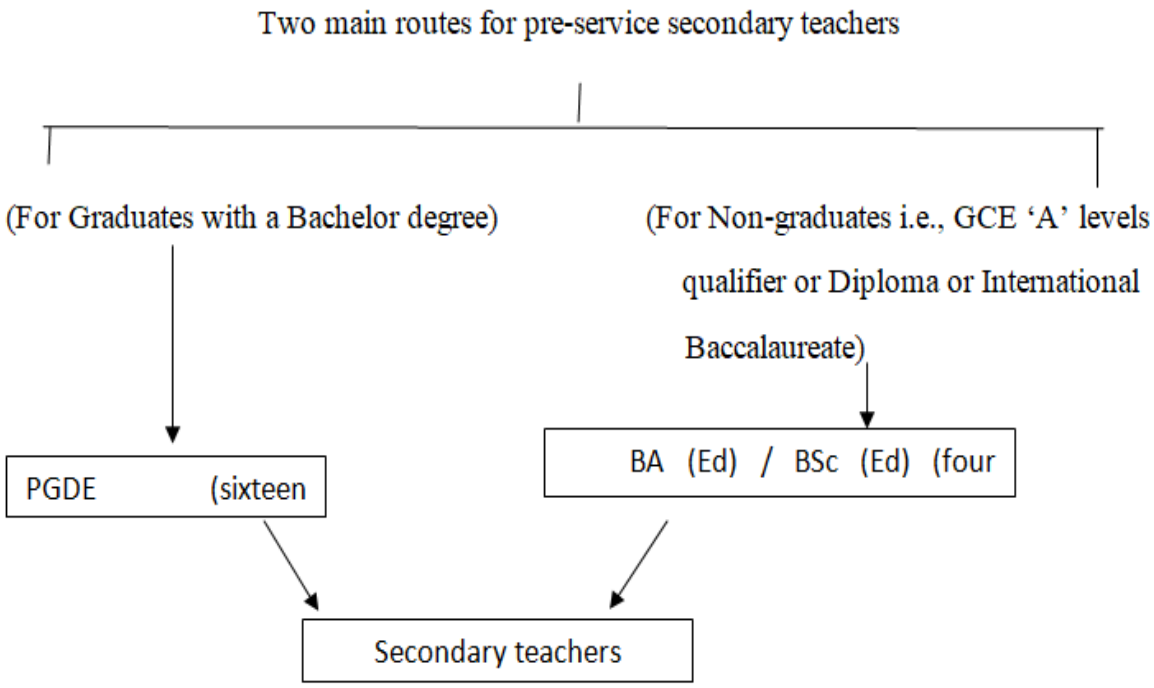

Fig. 1. Qualifications required for a secondary school science teacher

Characteristics of Teacher Education in Singapore:

- **Course structure:**

The aspiring secondary science teachers will have to take two teaching science subjects as a specialization. Along with acquiring specific subject knowledge in Biology, Chemistry, and Physics, they must be trained in assessment criteria, nature of science, science laboratory work, and understanding of implementing strategies. (Tan, 2018) A teacher with single-subject knowledge must have mastery of that subject. (Tan & Wong, 2007) Secondary science teachers have to cover more courses from subject-specific that is, major teaching area (Teo, 2002).

- **Practical training:**

  a) During the teaching practice pre-service teachers have to participate in microteaching,

  b) At the end of the Post Graduate Diploma in Education (PGDE) course, they must attend a four-week observation and a ten-week practicum in schools (NTU, n.d.a),

  c) At the end of the BSc(Ed) course, they must attend one-week observation in 2nd year along with a five week and a ten-week final practicum in 3rd and 4th year respectively (NTU, n.d.b),

  d) While completing school practicum, the mentoring of the pre-service secondary science teachers is done by senior teachers of observing school and a supervisor from NIE.

- **Mandatory training and certification:**

The candidates aiming for teacher ships in Government schools have to take mandatory trainings from the National Institute of Education (NIE), Singapore, which is a part of Nanyang Technological University (NTU), 'to be certified to teach'(TE 21, 2009).

- **Sessions:**

The academic year runs on a six-month semester basis. So, teachers, certified by the NIE, are employed in schools twice a year (Tan & Wong, 2007).

- **After training internship and recruitment:**

'Prospective students' (within top one-third of all trainees) undergo a series of stringent selection processes including interviews and tests by the MOE before they are selected. Upon selection, these students will be hired directly by the MOE and will be paid a salary (up to sixty % of a teacher's salary) when they undergo their pre-service teacher education at the NIE. One-eighth of the total candidates are selected by MOE who have to commit for threeyears of internship after training(Tan, 2018).

After an internship from NIE, graduate teachers are deployed by MOE to fill up the subject vacancies in school depending on their specialized subject during pre-service training. This appointment and deployment depend upon the expected feedback of enrolled student andgiven by the principal of the school each semester. Therefore, any type of shortage in teachers can be filled by MOE within six months (Tan & Wong, 2007).

- **Under-qualified teachers and Out-of-field teaching:**

MOE has taken a stringent policy for teacher recruitment, so no question of under-qualified teachers arises. MOE oversees the whole education system and thus surpluses and shortages are easily identified. Therefore, no question of out-of-field teachers is arising(Tan & Wong, 2007).

- **Induction Periods for graduates taking pre-service teacher training:**

MOE provides scholarships and salaries to all pre-service teachers. So, no need for an induction exam has arisen. Here the trained novice teachers are recruited directly in schools by the MOE (Tan & Wong, 2007).

- **Opportunity for Higher degree:**

University graduates get a chance to sit for the 'Qualification Entrance Examination' for enrolment to study post-graduate competency in education. This is applicable to secondary teachers working for two to four years (Tan & Wong, 2007).

- **Making graduate teaching workforce:**

MOE inclines on recruiting graduate teachers more than PGDE course holders, because, the formers are being trained in core-subject knowledge and pedagogical knowledge while the latters are being trained in pedagogical knowledge only (Tan & Wong, 2007).

Characteristics of PD in Singapore:

General Features of Teachers' PD:

Bautista et al. (2015) mentioned about five features of 'teacher PD' in Singapore. They were-

i. Subject specific connecting with classroom practice,

ii. Intensive and on-going,

iii. Providing opportunities to teachers like active learning,

iv. Encouraging collective participation of teachers irrespective of school boundaries,

v. Prioritizing school as well as national interests but not overlooking teachers' interests and needs.

➢ **Teacher Growth Model (TGM):**

The recent teacher PD program is the TGM launched by MOE in 2012.

- **Aim of PD:**

Through TGM, teachers can make themselves eligible to compete with 21stcentury challenges in education (AST, n.d.c)).

- **Duration of PD:**

Teachers are supposed to take one hundred hours of voluntary PD activities per year.On average,seventy-sevenhours of PD per year are completed by each teacher (Goh, 2016).

- **Activities in PD:**

In PD, teachers are updated with content knowledge, pedagogical innovations and new assessment approaches (Singapore, n.d.) through the following activities (Bautista et. al., 2015). Coherence of traditional or formal(offline) mode with informal (online) mode,

i. Workshops,

ii. Postgraduate programs (like Masters and Ph.D. as per teacher's choice,

iii. Conferences,

iv. Conventions and symposiums,

v. Related action research,

vi. Mentoring and coaching,

vii. School-university partnerships.

- **Procedure of PD:**

In this PD activity, a minimum of one member from the school's management makes discussions with the teachers taking PD about their all over progress and that would be the annual PD agenda viewing teachers' personal motivations and interests for school development and national curriculum development.

- **PD as 'continuum':**

PD in Singapore provides their teachers with proper learning opportunities to meet their 'personal motivations and goals' (Bautista et. al., 2015). They can continue their desired higher education (M.Sc. /Ph.D.) with their salaries and grants disturbed. Therefore, TGM represents it as a 'continuum' with initialization from preparation to induction continuing through development as well as growth and finalizing to careers, whichsustains life-long (Chong & Fong, 2000; Bautista, et. al., 2015). So teachers have different PD program as per their level of expertise '(beginner, experienced and expert)' (Bautista et. al., 2015), for example, at the beginning of teacher ship, the novice teachers has to participate in 20 hours of PD annually which is mentored by a senior teacher of that observing school. (Wong, 2013) According to Teaching and Learning International Survey (TALIS), this mentorship culture of senior teachers over junior ones is very prominent in Singapore. (OECD, 2014)

- **Funding:**

As suggested by UNDP (2018), like other high PISA-achieving countries, Singapore invests in education in an increasing way. MOE subsidized the total cost of PD (Wang, Kim, Lee & Kim, 2014).

- **Participation rate in PD:**

According to TALIS, OECD (2014), the rate of participation in PD activities by Singaporean teachers was higher than in any other countries (here thirty-four nations were considered).

➢ **Career Paths:**

In Singapore, teachers are offered with three different career tracks empowering their professionalism called career paths in which they have to choose any one. (Bautista, et. al., 2015) These are classified (Tan, Wong & Goh, 2010) as follows:

a) Teaching track,

b) Leadership track and

c) Specialist track.

- **Promotions:**

In each track of career, there are thirteen levels in which by promotion from one level to upper one, teachers get their salary increased with promotion. These promotions are examined by an educational performance supported by managerial system. It views 'teachers' professional practice', 'leadership management', and 'performance qualifications' (Tonga et al., 2019).

➢ **Teacher work attachment program:**

Since 2003, teachers can participate in 'experiential learning' both in the research sectors and in the business and community sectors through the 'Teacher Work Attachment Program' of a duration of three days up to one year in various public or private sectors of national and international level(Singapore, n.d.).

❖ **PD providers of Singapore:**

In Singapore, there exist mainly three PD providers (Bautista et. al. 2015). They are-

1. NIE,
2. AST and six Centres of Excellence,
3. PLC

The 'Enhanced Partnership Model' constantly forces on the triangular relationship between above three PD providing institution.

NIE (National Institute of Education):

- **Main courses offered:**

Since the 1970s, in coordination with MOE, NIE has acting as a PD provider (Tan et. al., 2010). Actually, NIE provides higher degrees like M.Sc., Ph.D., etc. to junior teachers, instructional leadership as a senior teacher's program to senior teachers, and educational leadership for departmental heads, vice-principals, and principals necessary for managing and leading in school. MOE (through NIE) provides various scholarship facilities to teachers seeking higher degrees on either a full-time or a part-time basis in Singapore or overseas (Bautista et. al., 2015).

- **Short courses offered:**

Short-term PD courses are offered by NIE for in-service teachers for various subject topics. These courses focus on content related to that subject, the development of its curriculum, related pedagogies, necessary assessment, and mostly on student learning. Most of these courses end with providing awards like- 'in-service diplomas' to appraise teachers' professional qualifications. For evaluation of these types of courses, NIE often recruits its own researchers as well as faculty members who make necessary changes in 'teachers' knowledge and classroom practices' (Bautista et. al., 2015).

- **Delivery modes:**

The delivery modes of these type of PD courses (both offline and online) involves-

a) Talks and lectures by subject specialists,

b) Project work,

c) Hands-on workshops,

d) Fieldwork,

e) Random action research,

f) Varieties of academic activities involving individual and collaborative works (Bautista, et. al., 2015).

- **Certification:**

Upon successful completion of the PD course (both in face-to-face and online modes), teachers are certified as per their attendance and performance in the course schedule in which they have to p0erform up to a minimum standard.

- **Research publication for 'continuous learning':**

Summary of the various research projects and programs are published in lucid language by NIE to develop continuous learningof teachers due to maximizing effects of research related to knowledge and classroom practice of a teacher. Three more in-house research publication of NIE that shares 'research findings'are-

a) Sing Teach,

b) NIE Research Brief Series and

c) Re Ed (Research in Education) (Bautista et. al., 2015)

1. Academy of Singapore Teachers (AST) and six centres of Excellence:

The PD provider that comes in second position in Singapore is the AST, formed in 2010, with 'six centres of Excellence'. AST was formed with a view to preparing 'active, committed and reflective teachers' whose roles in PD were not only as mere 'recipients' or 'implementers' but also as active 'developers of knowledge'(Hairon & Dimmock, 2011). Through AST, teachers from various institutions can participate in 'professional exchange', collegial sharing, and 'collaboration' to enhance Networked Learning(AST, n.d.b)) to make the motto "For Teachers, By Teachers" fruitful.

- **Structure of AST:**

AST consist of four'subject chapters'(part of disciplinary network learning communities) and sixcentres of Excellence (known as Academies or Institutes). (AST, n.d.a)

The subject chapters comprise four subject disciplines and they are-

a) Humanities,

b) Mathematics,

c) Science and

d) Others.

In Science, there are three subject-disciplines for secondary science teachers and they are-

i. Biology,

ii. Chemistry and

iii. Physics.

Among six centres of Excellence, the former four offer PD in different language training of subjects like- English, Mandarin, Malay, and Tamil. The rest two offer training in Music & Art and Physical Education.

- **Offline and online activities:**

I. Formal PD:

a) Lesson study,

b) Teachers' mentoring program,

c) Workshops based on school-oriented research methods,

d) Seminars and courses focusing content knowledge and pedagogical content knowledge,

e) Symposiums and conferences. (Bautista et. al., 2015)

II. Informal PD:

In online mode, teachers' PD is supported by an online platform 'One Portal All Learners' (OPAL), where teachers are provided with content repositories containing needful information and materials of learning. (Bautista et. al., 2015)

III. Reform-type PD:

With regard to 'reform-type PD', the main initiative is 'Teacher-Researcher Networks' which consistsof researchers who are also faculty members from NIE, specialists(mainly senior)from MOE and 'research activists'i.e., highly trained teacher-researchers with an aim to involve teachers in action research (Hairon, 2006). Teachers can find theirrelated research findings through various publications in 'forums', and 'annual symposiums' (Ellis, 2014) provided by AST which help other teachers in increasing 'their competencies for reflection and inquiry' in a similar classroom situation. (Bautista, et. al., 2015)

2. Professional Learning Communities (PLCs):

The third Singaporean PD provider is the 'Professional Learning Communities' (PLC), in which the schools act themselves as the 'learning organizations' from where the secondary science teachers can complete their PD within school settings. From 2009-2010 onwards, all public schools have to become PLCs as per the mandate of MOE. This policy was first implemented in Singapore. (Hairon&Dimmock, 2011) This was started with fifty-one schools in 2009 and by the year 2013, all MOE schools adopted the scheme (Lee, Hong, Tay& Lee, 2013).

- **Activities in PLC:**

PLC activities are supervised under 'School Leaders and Academies' to support the teachers with structures as well as resources to be involved in PD practices which are related, like- action research along with lesson study and 'learning circles' on the topics like- innovation in curriculum, practicing of teachers in a student-centric way, ICT, lesson planning in collaboration and learning through projects. (Bautista et al., 2015)

- **Duration, Certificates and Appraisal:**

Groups of teachers learning in a collaborative way are called 'Learning Teams' and they complete PD during fixed time slots that is, 'White Spaces'. The public-school teachers are encouraged to have at least one hour of PD weekly, while the learning team has the plan for 8-ten bi-hourly sessions in an academic year. These hours of PD contribute to the teachers' scheduled annual hundred hours of PD certificates and teachers' appraisal. (Bautista et. al., 2015)

- **Steps in PLC:**

Induced by the 'Japanese Lesson Study', Singapore introduced it in schools in 2005. In analogy with Singaporean action research, aim related to this lesson study is fostering inquiry in a collaborative manner and reflection in pedagogy driven by data within teachers. (Bautista et. al., 2015)

Teachers adopt the 'four cyclical and recursive phrases' in standard models (Tan, 2018) and they are-

a) Study phase,

b) Planning phase,

c) Analysis phase,

d) Reflection phase.

- **Initiatives and vision of MOE over PLC:**

Explaining the advantages of PLC, MOE created a handbook named 'PLC Starter Kit'.MOE funds for preparing a few teachers as 'research activists' with a vision that they would be able in the future to train their peers 'in conducting classroom-based research' (Ellis, 2014) along with some developmental work of curriculum innovation.

Teacher Education and PD viewing 21st Century Classroom:

An 'Integrated Continuum Milestone Program' named 'Teacher-Leaders-Program (TLP)' (as an initiative of AST under co-ordination with MOE) has been introduced to facilitate teachers' learning experiences which finally contribute to TGM in PD.

'V3SK framework'forms the underlying philosophy behind the teacher education at NIE, where the teacher education is pivoted strongly on 'three-pronged set of Values (V), Skills (S) and Knowledge (K)'.It represents a 'central pillar of values' of a '21st Century teaching professional', whichruns under the 'Teacher Education Model' for the teachers of 21st Century. (Seng, 2018).

Recent Scenario of Teacher Education and PD in the USA:

Qualification to be a science teacher:

Academic qualification:

A four-year bachelor's or undergraduate degree is required where fifty % or more teachers have their post-graduate degree (Ingersoll, 2007b). For elementary and secondary science teachers having a bachelor's degree is mandatory (Ingersoll, 2007a).

Professional qualification:

A professional degree ina science subject is required after an academic degree, which is the same as in the case of mathematics (Pramanik & Guha, 2018). In the USA, this is considered a program of five years for the preparation of teachers including their certification (Ingersoll, 2007a).

Certification:

Above ninety-one % of secondary science teacher in public school has full or regular teaching certificate and it may be in a single or different field. Seven % hold a less than-full certificate (i.e., temporary or provisional). Less than two % of public-school teachers do not have any teaching certificate. This data may vary from state to state in the USA. As no such national data are found. This may happen due to forceful appointment of uncertified teachers to the urban communities with low-income area to fill up the vacancies (Ingersoll, 2007b).

In the USA, an uncertified candidate can start his job in teaching and can get an opportunity to be certified later on (Ingersoll, 2007a).

Teachers from 'high-poverty schools' has less intention to have graduate-level degrees and full teaching certificate than those from the 'low-poverty schools'. The same trends follow in case of the teachers from public schools (Ingersoll, 2007b).

Teacher education before NGSS:

Overall control:

The educational governance of the USA exists in three or four tiers like- national, regional, local and school levels. It is 'unusually decentralized' in nature (Ingersoll, 2007a).

Several teacher-training institutes:

In the USA, teaching seemed to be 'non-competitive job', where the aspiring students could join teacher ship easily. (Lortie, 2002) where college graduates with average to low score generally were recruited in teaching(Henke et al., 1999). Thus, there were created several 'low-cost, dispersed and non-rigorous' institutions for the purpose of teacher-training. (Ingersoll, 2007a) after NGSS these institutions has been modified.

Course structure:

Aspiring students have to know the subject content knowledge along with adequate pedagogical content knowledge for their proper application. The major or minor fields associated (Ingersoll, 2007b) are-

- Science education,
- Biology/ Life science,
- Chemistry,
- Earth science/ Geology,
- Physics,
- Other natural sciences,
- Engineering.

Practice teaching and test for recruitment:

Practice teaching is required under supervision of educators prior to their employment. As in the USA, there exist different rules for different states; there is no strict rule for tests prior to the recruitment. But, in an overall manner 'test' or 'exam' is required (Ingersoll, 2007a).

Gender ratio in case of teaching:

In the USA, female candidates join the teaching profession more than male candidates do (Ingersoll, 2007a).

Ranking system:

In the teachership, there exists a 'hierarchy' (see Fig. 2) between teachers (Ingersoll, 2018)

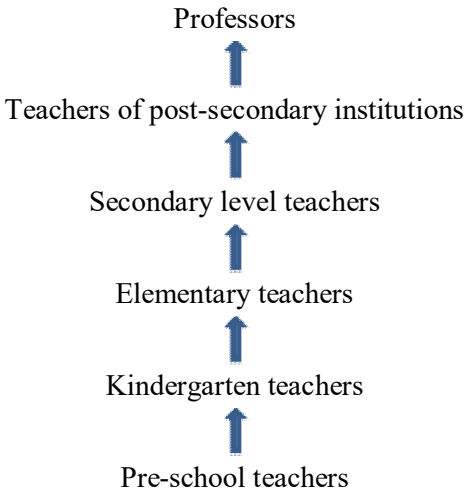

Fig. 2. Hierarchy of teachers

Out-of-field teaching and underqualified teachers: The problem of out-of-field teaching and under-qualified teachers is very prominent in the USA. Some reasons can be noted like-

- Preparing teachers in any major field during training and recruiting them for teaching the subjects that are not even in their minor fields,
- Huge difference between teacher requirements and teacher recruitment policy,
- Increasing teacher shortage due to lack of students' involvement in teaching,
- Numbers of teachers having English and Social science as major is more than that of having Mathematics and Science. So, while fulfilling science vacancies, sometimes science subject teachers are not available to recruit,
- Sometimes better performance shown by experienced (more than thirty to forty years) out-of-field teachers of middle school has been reflected in students' achievement and thus suppressing the necessity of subject teachers,
- Prerogative decisions of school administrators on school staffing always follow a 'top-down command model'.

❖ **Characteristics:**

i. Generally, in the middle school, the rate of out-of-field teaching is maximum,

ii. In the case of out-of-field teaching, the 'cross-school differences' exists between high-poverty schools and low-poverty schools,

iii. In more affluent schools, there exists out-of-field teaching but in small ratios,

iv. Private schools are more affected than public schools, though some large private schools are almost out of its effect,

v. Teachers, recruited for one field, have to teach in another field. Thus, underqualified teachers have been generated in second field(Ingersoll, 2007b).

Teacher education after NGSS:

Effect of NRC and NGSS on science teaching

On the basis of National Research Council report, "A framework for K-12 science Education" (NRC, 2012), an educational reform named "Next Generation Science Standards (NGSS)" was released in 2013. According to the report of NRC (2012), three dimensions of science standards have been described and they are-

a) Science and Engineering practices,

b) Crosscutting concepts,

c) Core ideas (Bybee, 2014).

The science standards in NGSS should maintain the following characteristics-

- Setting goals strictly for all students,
- Maintaining scientific accuracy,
- Being not more in numbers,
- Focusing all the three dimensions,
- Inclusion of performance expectations integrating the mentioned three dimensions,
- Getting information by teaching and learning-oriented research,
- Fulfilling students' needs and also that of states,
- Maintaining potential for compatible progression among grades and also within grades,
- Being sure about time spans, resources, and teacher experiences,
- Maintaining proper alignment with rest of the K-12 subjects, especially with the CCSS,
- Emphasizing on diversity as well as equity(NRC, 2012).

Effect of NGSS on the Science Education System

From NRC (2002), it could be concluded that there exist various 'channels of influence within the education system'. Bybee (2014) mentioned in his article that, for science education through NGSS, the three main channels or routes would be:

- Curriculum,
- Teacher development,
- Assessment and accountability.

These channels directly would help in the case of teaching in a classroom, learning, and thus achievement in learning. Here the necessity for initial preparation of teacher and their ongoing PD had been arisen.

Educational Shifts of science teachers in NGSS

Educational shifts through NGSS directly implies to the science teacher development (NRC, 2012) through the following steps:

a) Interconnecting and integration of three main dimensions of NRC (2012),

b) Confounding learning progression of science subject in students through their all over science education in K-12 stage,

c) Inclusion of engineering design not only in textbook, but also in science teaching technique adopted by the science teachers,

d) Emphasizing Nature of Science (NOS) by progressing through different 'grade bands K-2, 3-5, 6-8 and high school' to encourage 'scientific enterprise' through NGSS,

e) Coordinating Science with CCSS, which is related with English Language, Arts and Mathematics and thus provoking inclusion of assessment in science teacher education and rationalizing continuing teacher development.

Reforms for science teacher education due to NGSS

Maintaining standards for NGSS and balancing with educational shifts for science teachers some reforms could be taken according to Bybee, (2014) and they are-

I. Keeping in mind about students' needs and states' requirements, small revision of existing systems could be done with subsequent changes in increments,

II. Replacing components of the existing programs with units or elements that would be helpful for future teachers whether graduate or licensee,

III. Reforming the science teacher program in such a way that would give undergraduates some opportunities for learning science content and practices through a new or innovative way for their future teaching purpose,

IV. Covering science teaching in an integrated way balancing with crosscutting and STEM concepts.

Challenges born due to science teachers' preparation maintaining NGSS

1. Basic competencies

The disciplinary core ideas in Life Science, Physical Science, and Earth Science are quite similar to the previous standards given by the National Science Education Standard (NSES) (NRC, 1996). NGSS newly contributes to the crosscutting concepts and the NOS. It emphasizes 'Science and Engineering Practices' (SEP). So, the science teacher should have the basic competencies related to science content with adequate practices and corresponding pedagogical implications. The last one is followed by proper teaching methods and strategies full of argumentation and incorporation of engineering design, which actually results in science teachers in general and science teachers in particular (NRC, 2001).

2. Personal Qualities

For effective teaching, personal qualities are inevitable features for science teachers despite having a deep subject knowledge. It helps in their students' learning by apprehending students' perception, motivation, etc. (Bybee, 2014). In the report of the 'National Board for Professional Teaching Standards' (NBPTS), it was mentioned for the first time. After that, Bybee (2014) pointed it out in his article.

PD for science teachers before NGSS

To attain the 21st century competencies, the 'National Science Teaching Association' believed in making a high-quality teaching workforce (NSTA, 2006). To make it possible, a significant and fruitful PD for science teachers was required which must be provided by schools and oriented systems.

PD design for science teachers

i. Planning PD

- Selecting of science teachers' PD activities in such a way so that they must have a clear set of goals,
- Selection of learning strategies to meet the context, issues and goals of science teachers' needs and their PD plan.

ii. Implementing PD

- Implementation of PD should be done keeping in view science teachers' teaching schedule. It must be monitored and necessarily modified viewing teachers' and students' needs.
- PD should be made appropriate for both new and experienced teachers and might be given elsewhere from their own workplace.

iii. Sustaining PD

- PD should be considered as 'central to teaching' which needed the full support of school and local authorities to be successful,
- Resources like funding, time, course materials and of course but not least the ongoing support from school administration should be in a flow,
- For high quality secondary education, integration and collaboration between 'parents, community, scientists, university faculty and informal science organization' should work in hand in hand.

Specific needs for PD providers

- Developing PD programs keeping in mind the next-generation PD providers and the ongoing PD process,
- Establishing the importance of science teachers' PD program and encouraging leadership among educators,
- Maintaining high-quality in PD materials with adequate research-based tools and necessary strategies,

- Participation of PD providers in PD-oriented research.

Offline PD programs

The PD programs vary from state to state and district to district. Some of them are mentioned below:

a) Local Systemic Change Initiative (Banilower et al., 2007)

It was funded by the National Science Foundation (NSF), started in 1995 through the Teacher Enhancement Program (TEP), and then flourished after 2002. It was applicable for elementary and secondary science teachers (K-8) pursuing a minimum of 130 hours of PD. It was designed toprepare teachers for implementation of a 'district-designated' curriculum for science instruction (Banilower et al., 2006) to examine 'teachers' attitudes, perceptions and preparedness and classroom practices of PD' (Banilower et al., 2007).

b) STeLLA(Professional Development Programs, 2015)

The Science Teacher Learning from Lesson Analysis (STeLLA) program is a 'video case-based, analysis-of-practice PD program' applicable to upper-elementary teachers.

c) Reading Apprenticeship PD program (Greenleaf et al., 2011)

It is applied to 'biology teachers and their students'in a high school

d) Penuel et al. (2011) studied 'three different PD programs in earth science' and concluded that the three programs differed in teachers' management of delivery of curriculum in a classroom situation.

Online PD programs

Online PD programs for secondary science teachers were designed to create maximum 'high-quality' teachers who were 'flexible enough' to satisfy students' diverse needs and to improvise new classroom instructional practice balancing between 'districts and community' (NRC, 2007).

PD of science teachers after NGSS:

Vision of PD

Vision, as mentioned by NRC (2012) and NGSS (2013), can be improvised through three interrelated and substantial goals that affect secondary teachers' PD directly. They are- (Reiser, 2013)

1. Core Ideas

Shifting from extreme subject content orientation to deeper knowledge of core explanatory ideas,

2. Practices

Shifting from science inquiry method to 'science and engineering practices' (SEP) for self-explanatory ideas of various scientific phenomenon,

3. Coherence

Making a science learner able to build scientific new ideas throughout his lifespan spent in the science discipline and thus creating a sense of coherence.

Themes to be incorporated in teaching shifts

To make the above three visions successful,science teachers' PD is the only way out. In this regard, the important themes in teaching shifts should be incorporated. These can be summarized (Reiser, 2013) as follows:

- Learning should be based and structured on questioning a topic, not on the sequential, traditional presentation of it,
- This questioning must resultin some explanatory model. It should not be confined to only testing hypotheses,
- Answers should be in accordance with correlating the variables of science to construct a better explanation,
- Students are provoked for further investigation again and again,
- Teacher should support in development of knowledge related to practices,
- Shifting from bookish knowledge of textbooks to argumentation as well as reasoning,
- Maintaining a proper classroom culture.

Criteria of revised teaching shifts

To follow the above themes of teaching shifts, PD should maintain the criteria as follows- (Reiser, 2013)

- It should be studded with subject matter,
- It needs the involvement of active learning,
- It should be in accordance with teachers' self-practices,
- It should maintain coherency.

Recommendations

Recommendations to fulfilthe above criteria are- (Reiser, 2013)

a) Teacher should have adequate sense to construct and deconstruct classroom rules and regulations as per their needs for teaching purposes,

b) To make NGSS successful, teaching should be done in a collaborative way in the classroom they are teaching,

c) Capitalizing and responding more towards a cyber-enabled teaching-learning environment.

Options given for PD

To increase teachers' Content Knowledge (CK) and Pedagogical Content Knowledge (PCK), several options (Wilson, 2013) are given to the teachers completing their PD. Options are as follows:

- Studying together,

- Learning new technologies,
- Being accustomed to multi-media activities,
- Reading various cases and solving them.

Offline PD activities

Wilson (2013) has ornamented the PD system of the USA as the carnival of options. The author has mentioned different activities of PD like-

- Coaching,
- Mentoring,
- Summer institutes,
- Research experiences,
- School-based PLC,
- Introducing teachers to the new curriculum through various new events like 'make-and-take'.

Online PD activities

Some online programs (Dameron, 2019) followed in the USA are as follows:

- Coursera,
- edX,
- Alison,
- Udacity,
- Linkedin Learning,
- Skillshare,
- Codecademy,
- General assembly,
- Udemy.

These PD programs are directly or indirectly helpful for science teachers PD.

PD through the school reform

For successful PD implementation through school reform, five supports are required (Wilson, 2013)-

i. Proper leadership by the school head,
ii. Professional capacity of teachers along with their academics, collaborative quality, self-belief etc.
iii. Good understanding between parent-community and school,

iv. Student-cantered and student-friendly learning environments,

v. Instructional guidance including curriculum, teachers' tool etc.

Challenges faced by PD

Wilson (2013) has showed that three grand challenges faced by science teachers' PD are-

a) To find out more effective and more fruitful PD for science teachers which satisfy 'particular teacher's needs',

b) To prepare teachers well-equipped to face the challenges of scientific experiment done in NGSS classroom with adequate funding and proper experimental equipment,

c) To use the technology to its fullest to providehigh-quality PD to all science teachers.

Features need to be improved for science teachers' PD

According to Zhang et al. (2015), for Science Teachers' PD improvement and development in PCK is highly needed which directly correlates with 'learners', 'instructional strategies', 'curriculum' and 'assessment'. Most of all, science teachers should have PD in 'inquiry teaching' to face the new challenges due to NGSS. According to the authors, some features need to be emphasized during science teachers' PD and they are-

- Clearing the concept of common topics of science, like- ecosystems, force and motion,
- Being accustomed to use inquiry as a method of instruction in 'specific science topics',
- Programming PD of science teachers concerning their 'background in teaching experiences and grade level',
- Providing enough and adequate PD support to the science teachers who have adopted NGSS long with CCSS side by side for states in the USA.

Comparative analysis

Comparison with respect to Teacher Education

1. In India, there are many teacher-recruiting boards prevailing in different states, which are controlled by a central organization NCTE that follows the norms and regulations of NCERT.

2. In Singapore, the whole teacher education programs are centrally controlled by NIE under MOE. On the other hand, in the USA the whole system is decentralized.

3. In Singapore, mandatory free-of-cost training is provided to top one-third teachers who are selected through stringent selection process by NIE. After completion of training, with adequate grade-score, they are appointed directly to the secondary school by MOE without any induction periods passing through centrally controlled selection process. Whereas in India, student aiming to be a teacher get admitted to public or private teacher training institutes paying fees of their own choice (irrespective of admission test and generally depending on their academic score only) without any direct Government involvement. They have to undergo induction periods and have to sit for further competitive exams for recruitment. In the USA, teacher training is not done in free of cost.

4. In India, for secondary science teachers, two years B.Ed. degree is required for graduate students, whereas in Singapore, sixteen months PGDE diploma is sufficient for the same. But, for non-graduate students four years B.Sc. (Ed.) is required. For the USA, graduation is must with one-year professional degree in science or allied subject.

5. In case of subject specialization, Indian students have to take Physical Science or Life Science as method subject, whereas Singaporean students have to read any one among Biology, Chemistry and Physics of their own choice. In the USA, students have to take among Earth science, Biology, Physics and Chemistry as major or minor fields.

6. Practical training in classroom situation after completion of main training programs are more emphasized and time consuming which is regulated by strict monitoring system of senior teachers and NIE of Singapore. For India, it has been observed with comparatively less duration. But, here the monitoring process, especially through Government initiatives is very rare. In case of the USA, practice teaching is done under supervision of experts.

7. After training, certification is done in Singapore and USA, but not in India.

8. Singaporean teachers are recruited directly by MOE twice in a year depending on vacancies. Therefore, no questions of shortage, surplus, out-of-field, underqualified teachers arise. In India, recruitment of trained teachers is uncertain and not happened in a fixed interval. So there exists indiscrimination between the supply and demand of secondary science teacher. The matter of 'out-of-field' and underqualified teachers are creating big issues in the USA educational system especially in science fields.

9. For working teachers, pursuing higher degree is more feasible and profitable in Singapore and in the USA, than that of in India.

10. No promotion and ranking system exists in India, but exists in Singapore and in the USA.

11. In Singapore, pledge is taken to make graduate teaching workforce. No such initiative is observed in case of India. Graduation is almost mandatory for the USA.

12. During science teacher training, involvement through engineering practices and STEM strategy is remarkable in the USA and Singapore than that of in India.

Comparison with respect to PD:

1. Except for the USA, all PD programs of India and Singapore are funded by MOE preferably.

2. Value-based PD in all the countries has been observed for preparing 21st century enabled classroom.

3. Both India and the USA use single online portal for PD learning, for India it is DIKSHA and for Singapore, it is OPAL. For the USA various online programs are found in different states not through a single portal,

4. Separate PD providers work independently in Singapore under Government direction. So, PD program is well constructed with respect to subject content, methods, assessment, duration etc. in Singapore than that of in India. In the USA, various well-structured PD programs are running not necessarily under Government direction,

5. Singaporean teachers are proposed to have hundred hours of CPD annually, whereas in NEP 2020 it has been proposed for Indian teachers to complete fifty hours of CPD in a year. American teachers have been proposed to take 130 hours of CPD,

6. Mainly offline including some online activities are observed in Singapore, whereas in India mainly online activities are followed. Both online and offline activities are active in the USA,

7. In India, PD is practiced in discrete manner, while in Singapore, it is considered as continuum. In the USA, PD is also encouraged through a massive and open online mode,

8. In Singapore,and the USA, certification and promotion have been awarded to teachers participating PD, whereas in India, recently certification has been done to teachers pursuing PD, but providing promotion have yet to be introduced.

9. Rate of participation in PD programs is maximum for Singapore teachers than that of in other thirty-four countries. (OECD, 2014)

10. Three different professional tracks for teachers encouraging leadership and depending on their promotions have been observed in Singapore. No such ranking system is observed in India. Ranking system exists in the USA provoking leadership among teachers,

11. Teacher Work Attachment Program in national and international level to enrich teacher both theoretically and practically has been followed in Singapore. No such active program is observed in India. In the USA there are many PD programs alike,

12. Indulging teachers in continuous learning has been done through various Research Publications in Singapore mainly and in the USA. No such initiative has been taken in India.

13. In India, mainly informal type with a little incorporation of Formal type of PD is observed, whereas in Singapore and in the USA, Formal, Informal, and Reform types of PD are observed.

14. Separate discipline orientedPD Institutions along with language and co-curricular activities' training centres have been found in Singapore's AST. No such separate PD institution in India is found. Subject specific PD programs are formed in the case of USA.

15. Through PLC in Singapore and in the USA, schools can transform themselves into PD providers to fulfil the teachers' PD requirements instantly, whereas no such school-based PD can be provided by Indian school authority.

16. Through NEP 2020, teachers' appraisals are proposed for India, while in Singapore and in the USA, both the teachers' appraisals and promotions have been encouraged.

17. Formation of Research Activists through PLC has been done in Singapore and in the USA to pursue deep-rooted PD of teachers, while in India; no such specific activity is followed locally.

18. Lesson Study is followed in Singapore and in the USA, but India does introduce lesion study.

19. Science teachingsthrough core ideas and crosscutting concepts are found in the case of the USA followed by Singapore. In India, initiatives are taken after NEP 2020.

20. After NGSS(2014), science teachers' PD gets a new direction for the USA. After NEP (2020), India's PD system has been remarkably changed. Singapore also incorporates some PD programs to achieve the 21st century competencies.

Conclusions

The comparisons between secondary science teacher education and their PD existing in India, Singapore, and the USAhas been discussedhere. Through this study,the emergence and reflection of NGSS in American science teachers' PDshas been shown with necessary teaching shifts and requisite PD activities concerning PD needs of science teachers more precisely focusing on core ideas and crosscutting concepts. The advanced PD infrastructure of Singapore is depicted which is reflected through its performances in various international tests. In Singapore, the reform-type and school-based PD are more useful and easily accessible in practical situations, whereas in India, the PD programs are confined to theoretical knowledge mainly. Especially, for newly appointed teachers mentoring system is highly needed. Secondary science teachers should be encouraged through a suitableranking and promotion system supported by adequate research publication and inquiry-based teachingfor the betterment of science teaching. Through NEP 2020, India has stepped forward to improve its secondary science teacher education and PD programs maintaining an international level with an aim to achieve 21st century competencies to be adjusted in ever changing globalized world.

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