A Study on the Pedagogical Practices of Science in Various Indian School Systems

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Abstract

This qualitative comparative study on the pedagogical practices of science in Indian schools explores the differences in the science teaching practices at the various school boards and compares them with standard science pedagogy. Thirty selected teachers from multiple schools, which followed various state, central and international board curricula, were telephonically interviewed for the study and a Qualitative Comparative Analysis (QCA) of the data was conducted. The study gives insights into activity-oriented learning, argumentative learning practices, school environments, teacher-centred teaching and exam-oriented learning practices in Indian schools. Some practices help develop scientific literacy in students and others ruin the urge to explore and think independently. The science teaching practices studied here come under the umbrella of hands-on activities, peer collaboration and the use of argumentation. Conclusions are drawn to recommend administrative-level reconstruction of the school science classrooms, including activity-oriented and argumentative learning, the need to maintain a constructive, fearless school environment and essential modification, and improvement in the pedagogical practices according to standard science pedagogical practices. The paper also discusses the importance of quality improvement in teacher training programmes and the necessity of adopting new pedagogical practices for teachers.

Keywords: *Science Pedagogical Practices, Qualitative Control Analysis, Teacher Training*

Introduction

Science education in Indian schools is at a crossroads as it compares with students' scientific literacy from an international perspective and the ability of Indian students to pursue science education at undergraduate and postgraduate levels. As the existing

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practices in our schools demand exam-oriented rote learning, the students focus more on scoring marks than understanding the concepts or improving their skills. Science, which requires skills like observation, measurement, inference and critical thinking, is taught in the same way as any other subject without engaging the students with active learning practices. This teaching method can be credited with the Indian students scoring the last-but-one position (Pritchett, 2012) in the PISA (Programme for International Student Assessment) (Hartono et al., 2022) 2009, conducted by the OECD (Organisation for Economic Cooperation and Development). The idea of PISA is to assess the knowledge and skills of students through an internationally agreed-upon metric (Schleicher, 2023). Apart from theoretical knowledge, the skills mentioned earlier are necessary for a person to work in science and lead a meaningful life in society. Those skills will help a person to think systematically and rationally. The inability of Indian students to pursue an advanced study in science and the day-to-day increase in unscientific practices among the citizens demand an immediate revamp of science education in Indian schools. A high-level science process and scientific thinking skills in students help them lead a career in the field of science and to compete with international standards.

Even a dedicated review of literature in Indian science education reveals the insufficiency of adequate research papers and studies in the field. This gap in research in school science education needs to be addressed by researchers in science education. Koireng (2020), in the review paper regarding science education in India, has concluded that there has not been a study on the epistemology of science in the Indian context. An example of a vignette from an Indian classroom is given below:

A teacher stands in front of the class addressing students who listen in silence, obediently and speak only when asked to; a student stands up and reads from the textbook while the entire class is silent; a teacher demonstrates an experiment as students watch eagerly… (Chunawala and Natarajan, 2011) Babul Das (2022) talks about a STEM cliff, which is a drop in interest in science among students after the primary school years. In the article 'Science Education in India: A Misnomer for Scientific Temper', Sharma et al. (2020) attempt to identify how science education in Indian classroom settings prevents students from developing scientific temper because of the teaching method that focuses on

knowledge gaining without considering the students' ability to construct knowledge. In a study by Bansal (2017) that investigated the teachers' perception of inquiry-based science education in primary schools, a teacher's response is as below:

> "Teacher A suggested that she 'won't take a risk of spending time in inquiry which may hamper student achievement' since inquiry is not incorporated in the assessment process. Another teacher reported that they have learnt science using the lecture method, assuming students to be a blank paper that needs to be filled with information. Teachers in this study also reported that inquiry is an elitist practice where students play around with materials (ibid)."

A comparative study on pedagogical practices helps in intercultural understanding, learning from others to improve the educational systems, and to test the theory against empirical examples' (Schweisfurth et al., 2020). The central school boards in India are the CBSE (Central Board of Secondary Education) (School Connects, n.d.), the ICSE (Indian Council of Secondary Education), and the NIOS (National Institute of Open Schooling). Since NIOS is an open schooling system, this is not considered for the study. The different states of India follow different state boards for their schools. The state schools are selected from the two South Indian states, Kerala and Tamil Nadu. Though two international board schools of IGCSE (International General Certificate of Secondary Education) and IB (International Baccalaureate) are present in India, the more popular IGCSE schools are included in the study. The fifth category of schools belonging to the Krishnamurti Foundation of India (KFI) that work on the Indian philosopher Krishnamurti's ideals was included in the study out of the researcher's interest. These schools are known for their unique activity-oriented curriculum. An analysis of the science teaching practices of the different board schools is necessary to prescribe an adequate pedagogy of science by incorporating the practices from the different boards.

Prevalent Science Pedagogical Practices

The pedagogical practices of science in this study are classified into hands-on practices, peer-supported learning and the use of argumentation. Hands-on is an umbrella term for classroom demonstrations, experiments by handling materials, inquiry-based

teaching, model-making and field trips. Peer-supported learning includes collaborative activities with peers and teamwork. Students conduct argumentation on controversial topics, which requires them to take a stance and support their stance with evidence and claims. This is an essential skill to improve scientific thinking.

In a study that explored the effect of teacher demonstrations on students' understanding of redox reactions, the experimental group that learned the concept with demonstrations scored better on their attitudes and understanding of the concept. The study was conducted among 131 middle school 8th graders in Israel (Basheer et al. 2017). 'Demonstrations raise students' interest and encourage them to think about the topic' (Suomela, Juuti and Ahtee, 2013). A quasi-experimental pre-post study on the effect of practical work on students' academic achievement in science revealed that the experimental group scored significantly better than the control group, demonstrating the positive effect of practical experiments in science teaching (Shana and Abulibdeh, 2020).

Inquiry-based science teaching involves 'students participating in the learning process by asking questions, investigating problems and drawing conclusions while collaborating with others' (Attard, Berger and Mackenzie, 2021). This method is directly related to the actual field of science. In a study conducted by Şimşeka and Kabapınar (2010) on the effects of inquiry-based learning environments on the student's conceptual understanding of matter, science process skills and attitude towards science, the inquiry method had a significant positive impact on the conceptual understanding and the process skills of the students. The findings of the study by Biswal and Behera (2023) are congruent with the same result, advocating that science process skills are enhanced through inquiry-based learning.

A model, which is a 'representation of a phenomenon, object or idea' (Gilbert et al. 2000), is used in a science class to make the students understand the concept better. An example of a model is the use of different sizes of balls to represent the solar system. 'Understanding the models and the modelling process helps the students to develop a metacognitive awareness of the knowledge development within the science community' (Coll, France and Taylor, 2011). Field trips provide first-hand experience to the students, stimulate interest and motivation, and strengthen observation and perception skills' (Behrendt and Franklin, 2014). 'Learning outside

the classroom promotes students' cognitive, affective and social development' (Orion, 1993; Brody et al., 2008). Field trips can be conducted to places like the school garden, nature parks, botanical gardens, hospitals, science centres and other research centres (Rumjaun, 2017).

Peer learning necessitates the students to interact with their peers while doing a collaborative activity or learning a new concept. 'Through dialogues with the peers, the students construct and elaborate their ideas about the topic they learn' (Bereiter, 2002; Thurston et al., 2007). The interactions help the students clarify their doubts with their peers when they try to understand the concept together. Argumentation is an essential part of scientific inquiry. Through scientific argumentation, new theories are corroborated and new scientific laws are made. According to Deanna Kuhn (2010), using argumentation in the science classroom is essential to engage students in scientific discourse, which is a 'core epistemic practice of science' (Bricker and Bell, 2009). Both peer learning and argumentation should be incorporated into a science class to improve students' scientific thinking and collaborative skills.

School Education in India

The school education system in India is spread across the country and is under the control of the state and central boards of education. India, consisting of 28 states and eight union territories (Know India, n.d.), is governed by the state and central governments. The Indian states are divided based on their language (The States Reorganisation Act, 1956); hence, these states are linguistically and culturally different. There is no unified syllabus and curriculum for the different state schools in India.

The state schools follow the syllabi prescribed by the different state governments, whereas the central government board schools under CBSE and ICSE follow the syllabi prescribed by these central boards. The international IGCSE schools follow the syllabus from Cambridge University. The KFI schools, though they come under the ICSE board, follow child-centred pedagogy aimed at their all-around development.

Though the schools primarily follow the NCERT (National Council for Educational Research and Training) guidelines, different schools have different teaching practices for science as prescribed by the school management. The schools in India are

categorised as elite private residential or day schools managed by private educational trusts which follow either the state, central or international syllabi, central government schools (Examples are the Kendriya Vidyalaya and Navodaya Vidyalaya); schools belonging to the state governments of different states, and rural single or two-three teacher multigrade schools with meagre infrastructure and resources. Depending on the kind of school a student is studying in, the skills and academic outcome of the student may vary.

The available literature regarding the school boards in India distinguishes the different boards based on their teaching practices. Swaddle (2016), on their website, remarks that the international boards require teachers to be certified after completing training. The CBSE and IB boards provide ongoing training to the teachers once every year to every three years. Though the central boards of CBSE and ICSE are known to follow exam-oriented, lecture-method teaching, there have been modifications in their curriculum in recent times. CBSE, in 2019, revised the curriculum, focusing on the all-round development of students (CBSE, 2019b, p. 76). The international boards encourage more interactions with the students and involve them in more in-depth teaching practices (Swaddle, 2016). The website does not comment about the states' board schools since they are large in number and have many differences among states.

The Podium (n.d.) school website explains the practices of the different school boards in India. The website notes that ICSE exerts a high burden on the students and have less time for extracurricular activities. The website talks about the state board schools as having outdated teaching methods with a large number of students in the classes. The podium describes IGCSE as having collaborative learning with reduced competition and less student stress (ibid). According to Deeksha (n.d.), ICSE has a difficult syllabus and a highly rigorous grading system.

Khan (2021) holds that a school is judged based on the board of education it follows since the curriculum framework is based on the board. She feels that the 'CBSE board focuses on textual knowledge and the ICSE has a focus towards language proficiency'. There has not been an empirical study on the pedagogical practices of science on these different boards. This empirical study tries to differentiate these boards based on the pedagogical practices of science.

Science Education in India

After independence, the country's political leaders were aware of the role of science education in modernising the country (Kumar, Khandelwal and George, 1987). India's first prime minister, Jawaharlal Nehru (2004), believed that 'Science could solve the problem of hunger, poverty, sanitation, illiteracy and superstition', and thought that 'the future belonged to science'. After independence, India witnessed a tremendous increase in scientific and technological growth.

Teaching science inculcates in children's values and attitudes like scientific temper, rationality, reasoning, problem-solving and a knowledge of scientific methods (Joy, 2014). Science education helps the country progress by creating a scientific and technological workforce essential for continued economic growth. Indian science curriculum and policy documents target to eradicate poverty, free the masses from the social ills of superstitions and illiteracy, and train and create a cadre of scientists who will contribute to nation-building' (ibid).

How far did the Indian leaders' vision for advancement in the field of science reach after 75 years of independence? Varghese discusses the 'declining trend in Indian science education' (Varghese, 2008). Some universities in India have 'closed down their science department due to a lack of demand. Research in the field of science has also diminished' (ibid). This trend needs more exploration to bring progress in the field.

Padma Sarangapani (2014) describes 'The three challenges of school science education in India. The first one is the lack of labs and equipment in schools for teaching science. Second is the shortage of teachers who have studied science to teach science at the elementary level. The third challenge is deciding what should be included in the science curriculum. According to Sarangapani (p. 19), "The science curriculum must address itself constructively for the students to make sense of what they learn in science. Science teaching has to shift from a subject approach to a discipline approach for science to become a way of life." As Anu Joy (2014) mentioned,

> "The meritocracy and competitiveness promoted by science created disproportionate and inappropriate learning outcomes for children from different socio-economic

> backgrounds. Social mobility through science education is a distant dream for children from marginalised and rural communities since the science taught in school remains irrelevant to their lives. In India, science education remains elitist and inappropriate for children from heterogeneous socio-cultural and economic backgrounds. Most science teachers are trained to follow predetermined scripts and procedures to which the actual science classroom processes are confined..... Science teachers do not have autonomy over selecting content and choosing the pedagogical processes. This lack of teacher engagement makes science learning an alienating experience for the students."

There are two primary objectives for teaching science. Teaching science fosters budding scientists and builds a spirit of science in the students who will not work in science. So, what and how to teach science is a question (Sarukkai 2014). Teaching science should make students aware of the activities that take place in science and prepare them to be scientifically literate. Scientific literacy is the knowledge of scientific facts and theories, the skills required to perform in science, like observation, measurement, and inference, and the ability to think scientifically to solve general everyday problems and specific scientific issues. Science education should address these aspects of scientific literacy in schools.

Theoretical Framework

The theoretical framework for the study is drawn from the theories of learning and the psychosocial variables that affect science education. Behavioural psychologists Ivan Pavlov (Ploog, 2012), E. L. Thorndike (Schunk, 2012, 73), and B. F. Skinner (Schunk, 2012, 90) explain learning as acquired through stimulus-response connections. In a science class, when a student experiences a positive state of mind due to active science learning processes, it will make them like the subject and be more interested in science. If the science class uses monotonous lectures to teach the students, it can make them lose interest in the subject. So, according to behaviourism, if the students feel rewarded by science learning, it will strengthen their association with it and if they feel it is a punishment to sit in the science class, it can weaken their interest in science.

Jean Piaget proposed the stage theory of cognitive development (Inhelder and Piaget, 1958), which explained that a certain maturity

level is essential for an individual to understand and learn abstract concepts. According to Piaget, the formal operations stage starts at 11 to 12 years of age and enables the child to understand scientific concepts. Learning is contextual and requires knowledge based on which new learning occurs (Hein, 1991). Piaget (1978) holds that children construct knowledge through accommodation and assimilation based on their existing knowledge.

Vygotsky (1930) believed that "human cognition and learning are social and cultural in reality and not based on individual experiences alone'. He transformed the meaning of learning from information acquisition to concept formation. According to Vygotsky (p. 24), intelligence develops when the child uses language and practical activity. This theory justifies the importance of hands-on activities and classroom discussions in science learning. Vygotsky (p. 86) explained the 'zone of proximal development" (ZPD) as the difference between the ability of a child to do a task alone and what she will do if a person supports her. ZPD prescribes relevant interactions with others that will help the child learn and perform a task that she would not be able to do by herself otherwise. ZPD emphasises the importance of teachers and peer interactions in learning.

John Dewey, the proponent of experiential learning, believed that 'inquiry should be the primary source of knowledge' (Bridges, 2007). Dewey's social and educational theories are based on his thoughts on democracy and problem-solving (Williams, 2017). Dewey stressed the importance of learning by doing (Dewey, 2001, p. 192). He asserted that learning does not occur if the facts and information are conveyed directly to the students. It requires the students to interact with their environment (p. 27). Experiential science learning includes pedagogical practices like experiments with materials, inquiry-based learning, model-making, field trips and classroom demonstrations.

The science pedagogy is evolved and updated by the teachers and researchers in science. Different theories of learning have been proposed by psychologists as the field of psychological research progressed. Advancements in educational psychology brought out the psychosocial variables that enhance learning. The pedagogical practices of science connect to the theories of learning and the psychosocial variables related to learning, such as classroom environment (Fraser, 2007, p. 103), autonomy (Aubusson, Griffin, and Kearney, 2012, p. 1129), control or self-regulation,

self-determination and goal-directed behaviour (Koballa and Glynn, 2007, 89). Science pedagogical practices should be designed based on the learning theories mentioned above and should consider the psychosocial variables that enhance learning.

Methodology

The present study on the pedagogical practices of science in Indian schools was conducted through telephonic interviews with teachers handling science classes from middle school grades six to eight. The snowball sampling method was used to collect data by reference from one teacher to the other. The teachers were asked open-ended questions regarding the practice of science teaching in their respective schools.

Research Questions

1. How is science taught in Indian secondary schools?
2. What are the possible shortcomings of the practices of teaching science in schools in India?
3. What are the possibilities for improving school science education in India?
4. How do the different school categories differ in their science teaching practices?

Methodology

A total of 30 teachers interviewed belonged to the different board schools and states in India. Each interview lasted from 45 to 75 minutes. A qualitative control analysis (QCA) (Ragin, 1984) was conducted for the components of science pedagogy to determine the frequency of each variable. The factors studied are hands-on activities (including classroom demonstrations, inquiry-based learning practices, handling and manipulating materials, model-making, and field trips), peer-supported learning activities, and scientific argumentation. The school category that used more active science teaching methods was also determined through calculations. The calculations are based on the method from the 'better evaluation' website (Davies, 2019) that explains how the data is worked out using Boolean algebra (Ragin, 1984). If present, each pedagogical practice is given a score of one and the absence, a score of zero. The total score of each board and each variable

is calculated by adding the rows and the columns. Each school board's average score is calculated by dividing the total score of the teachers on the board by the number of teachers who responded.

The seven practices of active science teaching are tabulated based on the responses of the teachers in the interview. After the initial rapport building and questions about their qualifications and experience, the researcher had an in-depth interview regarding each of the active science teaching practices. The teachers were asked to give examples of certain aspects when it was not clear to the researcher. The points from the interview are noted down for each teacher separately, which are then analysed by tabulating each of their responses for each of the practices. In this way, a Boolean algebra matrix is tabulated and the total score for active science teaching practices is calculated.

The teachers belonging to each board category are as follows. Ten teachers from SSLC board schools, eight teachers from CBSE, five teachers from ICSE, four teachers from IGCSE and three teachers belonged to KFI. The SSLC schools are the state board schools, and the sample has schools belonging to the states of Kerala and Tamil Nadu. The CBSE and ICSE schools following the central syllabus also belong to these states. IGCSE schools, which are relatively limited in number, belong to the states of Kerala and Karnataka. There is a total of seven KFI schools in India. Out of the three teachers interviewed from this school category, one belongs to Sahyadri School, Pune (Maharashtra State), and two belong to The Valley School, Bangalore (Karnataka State).

Conclusions are drawn about the school category that received the highest score and the pedagogical practice used by most teachers. The insights from the teachers regarding their science teaching experiences are explained in the following sections.

Results and Discussion

The significant results of the survey are depicted in Tables 1, 2 and 3. Table 1 shows the matrix of the responses of 30 teachers from different school boards on each of the active practices and the total for each category is calculated. Table 2 shows the scores of the different school boards on the pedagogical practices of science, including hands-on activities, peer learning and argumentation. Table 3 has the board-wise score on the use of science pedagogical practices and the average scores for each.

Table 1: The Boolean Algebra Matrix of the Teacher Responses for Active Science Teaching Practices

ACTIVE SCIENCE TEACHING PRACTICES									
INITIALS	BOARD	Classroom Demonstration	Experiments Using Materials	Inquiry-based Learning	Model Making	Field Trip	Peer Collaboration	Argumentation	TOTAL - BOARDWISE
RM	SSLC	1	0	0	0	0	0	0	35
JN	SSLC	0	1	0	1	1	1	0	
KL	SSLC	1	1	0	0	0	1	1	
TP	SSLC	1	1	1	1	1	1	0	
MR	SSLC	1	1	1	0	0	0	0	
LJ	SSLC	1	0	1	1	0	1	0	
SM	SSLC	1	1	0	0	0	1	1	
FR	SSLC	1	1	0	1	0	0	0	
AY	SSLC	1	0	1	0	0	1	1	
AR	SSLC	1	1	0	0	0	0	0	
AN	CBSE	1	1	1	1	0	1	1	34
SW	CBSE	1	1	1	0	0	1	1	
JJ	CBSE	1	1	1	1	0	1	1	
UD	CBSE	1	1	1	1	0	1	1	
TN	CBSE	0	0	0	0	0	1	0	
SM	CBSE	1	0	1	0	0	1	0	
EL	CBSE	0	1	1	1	0	1	0	
AY	CBSE	1	0	0	0	0	1	1	
MH	ICSE	1	0	0	0	0	0	0	18
NR	ICSE	1	1	1	1	0	1	0	
RJ	ICSE	1	0	0	1	1	0	1	
MA	ICSE	0	0	1	1	0	1	0	
DM	ICSE	1	1	1	1	0	1	0	

SA	IGCSE	1	1	1	1	1	1	1	24
IA	IGCSE	1	1	1	1	1	1	1	
AN	IGCSE	1	1	1	0	0	1	0	
JH	IGCSE	1	1	1	1	0	1	1	
AR	KFI	1	1	1	1	1	1	1	20
DS	KFI	1	1	1	1	1	1	1	
RJ	KFI	1	1	1	1	1	1	0	
TOTAL SCORE		26	21	20	18	8	24	14	

Table 2: The Total Score of Different Board Schools on the Hands-on Science Practices, Peer Learning and Use of Argumentation

Hands-On Science Teaching Practices							
Type	Demo	Materials	Inquiry	Model	Field Trip	Peer Learning	Use of Argumentation
SSLC (N=10)	9	7	4	4	2	6	3
CBSE (N=8)	6	5	6	4	0	8	5
ICSE (N=5)	4	2	3	4	1	3	1
IGCSE (N=4)	4	4	4	3	2	4	3
KFI (N=3)	3	3	3	3	3	3	2
TOTAL	26	21	20	18	8	24	14

The teaching experiences of teachers range from 2 years minimum to a maximum of 31 years. The average teaching experience of the teachers is found to be 16 years. Eighteen out of the 30 teachers were post graduates (Masters in science), ten were undergraduates (Bachelor of Science), and two were engineering graduates. Table 2 is drawn based on the scores of each component of the pedagogical practices of science calculated separately for the different board schools. The rows represent the school boards, and the columns represent the variables. The number of responses from each school category is marked below them in brackets in

the first column. The active practices include demonstrations, experiments by handling materials, inquiry-based teaching, model-making, field trips, peer-supported learning and the use of argumentation. From Table 2, it is understood that 26 out of the 30 teachers use classroom demonstrations while teaching science. They do it by bringing materials from the lab to the science class or by taking the students to the lab to demonstrate. Twenty one teachers reported providing the students with materials to conduct hands-on experiments. Some of the experiments reported by the teachers include finding the magnetic field using magnets, using water-filled bottles with holes at different positions to understand the variations in pressure, and an inertia experiment with a tumbler and coin.

Classroom demonstration is the most used method out of all the components of science pedagogical practices. Activities with materials and observing demonstrations improve the students' science process and observation skills. These activities help them make inferences and conclusions, skills essential to work in the field of science.

Inquiry-based teaching helps the students to develop a spirit of inquiry, which is essential for today's information-overloaded world. Twenty teachers reported the use of inquiry-based teaching. The teachers reported doing activities like growing plants at different conditions and observing the differences, asking what happens if the magnet is taken out in the electromagnetic induction experiment, and what happens if a person jumps out of a running bus. Some teachers give challenging questions to the students and make them find solutions by referring to books and discussing with others. Sometimes, the students are made to do a case study on topics, for example, pollution or the use of plastics. This method helps to develop an inquisitive mind in the students.

Eighteen teachers reported making the students do either still or working models. Teachers reported doing a project by making a rainwater harvesting model, a flower cross-section using woollen thread, a pinhole camera and an electric circuit. These activities are essential for a science class to develop autonomy and independent thinking in the students.

Out of the 30 teachers, only 8 reported regular academic field trips as part of the curriculum. These teachers do it with the students by going out of the school to collect leaves, observing the stream nearby, or regularly observing the plant growth on the

nearby farm. Most of the remaining teachers have reported going on a trip once or twice a year as an excursion. Field trips enable the students to observe science in their surroundings, thus making a connection between life experiences and science. Regular field trips must be incorporated into the science curriculum so that students will feel that science is part of their everyday lives. In the peer-supported learning category, 24 out of the 30 teachers responded positively. Many teachers explained that a weak student and a high achiever are paired together to benefit the slow learner. The high achiever also benefits since it makes her thorough with the topic by explaining it to the other students. However, for science activities, no frequent in-class interactions are reported. The interactions with peers occur when the class is divided into small groups, and each group is given an assignment, mainly for exam preparations and project preparations. In the variable, 'use of argumentation', 14 teachers responded in affirmation. Lack of awareness among the teachers, the vastness of the syllabus and hence the lack of time are the significant reasons for teachers not using argumentation practice as part of science teaching. Argumentation is the second least used practice by science teachers, next to regular field trips. The less use of argumentation and discussion in class is attributed to teachers' worry about losing control of the class if the students are made to talk freely. The vast syllabus also makes the teachers use more teacher-centred teaching methods to complete the chapters before the exams.

Table 3: Score on the Use of Science Pedagogical Practices for the Different School Boards

Type of Board	Total Score	Average
KFI (N = 3)	20	6.67
IGCSE (N = 4)	24	6
CBSE (N = 8)	34	4.25
ICSE (N = 5)	18	3.6
SSLC (N = 10)	35	3.5

Table 3 shows the total scores of each school category on the science pedagogical practices and the average of each category. It is evident from the table that the average score of the KFI schools on the use of science practices is the top. The KFI schools scored the maximum average of 6.67, whereas the IGCSE scored the

second-highest, with an average of 6. CBSE schools scored an average of 4.25, whereas ICSE and SSLC board schools scored the least, 3.6 and 3.5, respectively. The result clearly shows that the significant school categories in India, the CBSE, ICSE and SSLC boards, scored the least in active science learning practices.

The KFI schools work on J. Krishnamurti's philosophy of education: "The right kind of education while encouraging the learning of a technique should help to experience the integrated process of life" (Krishnamurti, 1955; Krishnamurti, n.d.). The KFI teachers reported going on a field trip inside the campus since most KFI schools are located in large areas. They collect leaves, observe insects or reptiles and discuss them in class. These schools follow the innovative pedagogy of vertical classrooms, called multiage classrooms, where students of different grades sit together in one class. In most of these schools, this grouping is done as a pedagogical experiment in lower classes below 8th grade. The KFI teachers have autonomy regarding class activities and are not bothered about exams until class eight.

The second-highest score on the use of pedagogical practices of science is for the IGCSE syllabus schools, with an average score of 6. The interviews with these school teachers revealed that they follow most practices regularly and have flexible seating arrangements to do these activities. The teachers encourage peer interactions and have regular debates and discussions in class.

The economic divide is evident in admissions to schools or admissions to the top-most institutions in the country, which require money to enroll in the coaching centres to crack the entrance exams. The same difference is reflected in this survey, where the elite schools learn science most desirably, and the vast majority learn by rote to pass the board exams and score marks to enroll themselves in mediocre institutions. Such students will find it challenging to make sense of their education since they do not know how the subjects they study can be used to manage their daily lives.

The average score for science-related pedagogical practices for CBSE is the third highest, with 4.25. This score can be attributed to the revision in the syllabus, as reported by some of the teachers. In 2019, 'art integration' was incorporated into the curriculum for the students to have a more experiential form of learning (CBSE, 2019a). The teaching takes an interdisciplinary approach. A teacher (JJ, a CBSE teacher from the survey) reported, for example,

"When the theme is water, all the subjects will have water-related activities. For languages, they write an article on the theme; in maths, they do calculations on the capacity of a water tank; in geography, a map of the rainfall is made; history deals with the reasons for climate change; and in chemistry, they do electrolysis experiments." The effect of the revised syllabus is slightly reflected in this survey. The scope of this revision is clear from the below statement, as mentioned in the NCERT guideline for Art Integrated Learning:

"Art Integrated Learning (AIL) was envisaged as a pedagogy applicable to all levels of school education to develop the target areas of cognitive, socio-emotional and psychomotor domains of the learner. At multiple levels of the teaching-learning process, Art integrated learning has opened spaces for the existence of a learning that is both inter-disciplinary and holistic" (NCERT, 2019).

From the survey, it is noted that SSLC and ICSE come at the lower levels of the table, showing that these syllabi are less activity-oriented and more exam-centred. One teacher (AB, an IGCSE teacher from the survey) reported that she has experience working with both CBSE and ICSE syllabi and that "ICSE is an exam-oriented syllabus and students in that school resort to rote learning more often." A teacher from an ICSE school (RJ, from the survey) also reported that "if any student comes from other board schools to this school, they struggle to learn since it is more content-oriented." Another ICSE teacher (MA, from the survey) reported that "the students in this school in 10th grade are learning physics topics equivalent to degree level physics." These statements show why the ICSE scored among the lowest in active science pedagogical practices.

Many SSLC teachers have reported that the syllabus is vast and because of this, they have to use more of the lecture method to finish the portions on time. A government school SSLC teacher in Tamil Nadu reported that the students in their middle school come from a single-teacher school and cannot even write correctly. Quoting her, 'They do not know the alphabet in 6th grade. So, the initial months of the school year go by, teaching them to read and write. Only after that, they can start teaching the grade-level topics.' This teacher, the school's headmistress, reported, "The teachers have less commitment and take all possible leaves available in the government structure. They are least bothered about finishing the content on time".

According to the stimulus-response learning theories, if the students have a pleasant state of mind while attending science class, they will like the subject. Activities and interactions in the class will give them a rewarding experience, and the students will become interested in science and improve their scientific skills. When a teacher engages in activity-based teaching, she considers the students' cognitive development level to plan the activities. The teachers of the KFI and IGCSE schools have reported how they plan activities for the class, like 'doing a whole class project on making bio-enzymes using orange peels or making a model of the Kaveri River from its origin.' These teachers engage in constructive science teaching methods by helping the students build upon their current level of cognitive development.

Vygotsky's (1930) social learning can be observed in these activity-oriented classes, where the students interact with their peers and the teachers in a free and contented environment. The students come to know about different perspectives when they interact with others. Classroom discussions and argumentation help them convince the other students about their standpoint by presenting evidence for their claims in the most acceptable manner. A proper argumentation exercise teaches the students that there are several angles to the same issue and that there is no single solution to a problem. They learn to reach a consensus on specific aspects of the issue and negotiate with others when there are conflicting issues.

As stated earlier, according to Dewey (2001), learning does not occur if the facts are directly conveyed to the students. The students' interactions with their environment help them understand scientific concepts and learn by manipulating the materials in the environment. The interest and attitude of the students towards science can be assessed in a similar comparative study to understand if the pedagogical practices affect these variables. The scope of this paper does not cover these aspects. Making the students engage in active science learning helps them become more self-determined since it gives them control and more autonomy. The students learn to engage in goal-directed behaviour since they know the purpose of the activities they do in a science class, whether making a model, proving a point, or participating in peer learning.

Conclusion

The above observations revealed that most of the curricula, except those observed in KFI and IGCSE schools, do not follow many active pedagogical practices of science. The curricula followed by KFI and IGCSE schools have more active practices like hands-on learning, classroom demonstrations and field trips, peer interactions and discussions. The KFI schools follow a syllabus that is integrated with activities with a fearless learning environment as envisioned by its founder Jiddu Krishnamurti. Since the KFI students have a good foundation laid by the flexible activity-based teaching system, it can be assumed that these students will perform well in the higher grades with better science process skills and scientific thinking skills. IGCSE students may also show better scientific thinking and process skills as these schools follow more active teaching methods.

The schools that follow state or central government curriculum lack the above said science pedagogical practices, or conduct some of the activities for a name's sake. Many teachers stated that they do not get enough time to discuss topics with the students because of the heavy content of the syllabus. This unnecessary workload in the classes prevents students from conducting their experiments and discussing their observations and findings with the peer group and the teachers. The absence of these vital science pedagogical practices forces students to learn by rote and engage in exam-oriented study. Eventually, their quest to explore and curiosity for deeper knowledge and ability to analyse and conclude, by formulating hypotheses, will diminish.

It is crucial at this time for the government to intervene in school science education to make constructive changes in the practices of science pedagogy in schools and make it on par with international standards. Substantial change is required in the epistemological outlook and practices of science teachers. The change has to be initiated from the teacher training institutions. Hands-on science learning, the importance of peer-supported learning, and the advantages of using argumentation in science class have to be taught to future science teachers. A teacher reported that some of these exercises using hands-on activity-based teaching are followed in the B.Ed (Bachelor of Education) course, but when the teachers join a school, they become part of the pattern followed in that school.

Policy decisions must be made at the government level to ensure that the schools follow activity-based learning and that the teachers are given on-the-job training by expert teams to follow these practices. Regular follow-ups with close inspection and proper rectifications are necessary for sustaining these teaching practices in these schools. The government should support the schools by providing the hands-on materials and necessary infrastructure to ensure that these practices are followed.

Implication of the Study

There is a need to change the science teaching practices that are followed in the common Indian schools. The science class should have hands-on activities, peer interaction, and scientific argumentation exercises to improve the students' scientific skills. The class strength has to be brought down, the duration of the science class has to be extended to enable activity-based teaching, and flexible seating arrangements should be provided to conduct activities in the class. The content of the syllabus needs to be reduced to enable the teachers to use more activity-oriented science teaching.

The KFI and the IGCSE schools follow more activity-based science teaching practices than other Indian board schools. These two groups are the big-budget elite schools of India. The government can make necessary improvements in infrastructure and resources to make its schools more activity-oriented by incorporating the changes mentioned above in its schools.

The teacher training institutions should be aware of the use of the pedagogical practices of science from the middle school level, and steps should be taken to provide on-the-job training to the science teachers. Constant monitoring and mentoring are required to help science teachers use more activity-oriented methods in teaching science.

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