Doing Activities in Science: A study of middle school classrooms

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Abstract: This study examines the nature and purpose of science activities in middle school classrooms across a cross-section of schools in Delhi and explores the relationship between teachers' beliefs about science education and their classroom practices. Using a qualitative microethnographic approach, the researcher observed 24 science teachers from nine low-, middle-, and high-fee schools in Delhi over six months and conducted semi-structured interviews with them. The findings reveal considerable disparities in the availability and use of science activities across different school contexts. In most classrooms, activities were primarily used to verify concepts already taught rather than to promote inquiry, exploration, or the development of scientific process skills. Students were often expected to follow prescribed procedures or merely record experiments without actively engaging in scientific investigation. Teachers identified constraints such as limited resources, lack of time, heavy workloads, examination pressures, and insufficient institutional support as barriers to implementing experiential learning. The study concludes that meaningful science education requires not only improved infrastructure but also sustained professional development, supportive school environments, and pedagogical reforms that encourage inquiry-based learning. These findings are particularly relevant in the context of the National Curriculum Framework (2023), which advocates active, hands-on engagement as the foundation of science learning.

Keywords: science education, activities in science, science policies

INTRODUCTION

There are serious challenges facing our country – poverty, ill health, hunger, unemployment, malnutrition, poor irrigation, unsafe drinking water, habitat loss, pollution, urbanization, and poor sanitation. On the other hand, communication and information technologies have developed at an unbelievable speed across the globe, compelling us to cope up with the changing times or lag behind. It is vital to forge ahead to usher in effective education in science, yet retaining our unique culture. This need is not new and has been constantly realized by the educationists.

The requirement for a broad based (liberal) science curriculum for the entire human population has been emphasized at various times in recent history by educationists and rational thinkers (Dewey, 1916; Russell, 1926; Kothari, 1964). Expressing this view, the Education Commission (1964-66) constituted by the Government of India, emphasized a "Science for All" programme. The National Policy of Education (1986) endorsed the view of a liberal science curriculum.

The salient features of science education for the first ten years of schooling constitute the ideas of science for all. Most students are unlikely to be producers of scientific knowledge. Hence the emphasis should be to help students become better-informed and hence more intelligent consumers and users of information about matters involving science, technology and society. Development of problem -solving, communication and decision-making skills which ensure human welfare would lead to a better preparation for the future than mere pedantic scholastic learning.

The Secondary Education Commission (1952-53) enjoined general science courses for the middle stage. "It is neither possible nor desirable to teach children all the facts even the most important of them, that they are likely to need in later life. It is more important to awaken interest and curiosity in the child's mind to teach him the method and technique of acquiring knowledge than to burden his memory with miscellaneous information."

An Extension Services project (Govt of India, 1955) was taken up during 1955-56 wherein centres were established in 24 post graduate training colleges to provide in-service training to teachers by organizing seminars, workshops, etc. Thirty research projects were taken up in 21 teacher-training institutes to improve science teaching. Science clubs were sponsored in 350 schools to encourage schoolteachers to introduce laboratory exercises and improve science instruction. The Indian Parliamentary and Scientific Committee (IPSC, 1961) observed that during the last 25 years, objectives of science teaching have changed little, while changes in the nature of science, that ought to be taught have greatly changed. They recommended a reorganisation of the science curriculum to include nature studies at the primary level, general science at the middle level and separate disciplines (physics, chemistry, biology) at the secondary level of schooling.

The UNESCO planning mission (1964) stated that science education is mostly carried out by verbal methods due to a considerable shortage of teaching equipment and also because many teachers have not yet mastered the methods and techniques of school equipment

The Education Commission (1964-66) gave importance to science education. It suggested a primary stage of 4 years (class I-IV) followed by a "higher primary stage of 3 years (classes V-VII). The Education Commission also emphasized the experimental approach to science. The Commission (1964-66) suggested a "Science corner in lower primary schools and a laboratory-cum-lecture room in higher primary schools" as essential requirements.

The National Curriculum for primary and secondary education – A framework (with the acronym NCF - 1986) advised "that a child studying science for ten years will acquire observation and analytical skills for self-regulation, ability to use tools, apparatus, instruments and equipment appropriate to his immediate and future needs; ability to identify the factors operating in his system and understand their causal relationship; collect, classify, interpret data and make reasonable inferences. He will also understand the basic scientific concepts, laws and principles and apply them in solving problems."

NCF - 1986 recommended that in the primary stages, "the child should be able to observe things and occurrences in the environment and formulate precise questions relating to his natural and social environment. He should be able to systematically record and classify the observations about the various living and non-living things around him, collect information from daily life, understand cause and effect relationships through simple experiments, activities and demonstrations. He should also be able to identify the resources in the locality and develop habits of using them properly. To make his observations precise, he must develop skills of measuring length, area, volume, time and temperature, etc. At the upper primary stage, the child is expected to consolidate and strengthen the abilities acquired earlier. In addition, the objective should be to develop an understanding of certain physical, chemical and biological principles and their relationship to the operation of scientific principles in nature as well as in daily life. The child should be helped to understand scientific symbols and formulae, etc., and acquire skills in designing simple experiments to seek explanation of natural phenomena."

The revised version of the National Curriculum for Elementary and Secondary Education (2000) included three aspects of the study of physical and natural environment under science education. These were "the pupil has to learn about flora and fauna, natural resources, sources of energy, etc. Secondly, the learning here should take place to a great extent through the learner's physical and natural environment implying thereby a systematic observation and explanation by applying scientific procedures of study. Thirdly learning should also be for the physical and natural environment, meaning thereby that it should be aimed at the development of a genuine concern, sensitivity and ability necessary for the preservation and protection of physical and natural resources."

NCF-2005 focussed on hands-on-activities and gave importance to connecting science with the world around the child. It recommended developing science corners in the classroom and use of science kits as well as low-cost, no-cost readily available material for doing and learning science. NCF-2005 emphasised process skills of science to enable children "how to learn". It suggested reforms in the examination patterns to include activities and experiments.

NEP-2020 has emphasised holistic and multidisciplinary learning by designing curricular goals and competencies in between science and other curricular areas. It has recommended looking at concepts through socio-cultural, economic, emotional, and scientific lenses.

The national curricular framework for school education (NCF-2023) has reiterated the importance of "doing science" for conceptual understanding and capacity building. The focus is on hands-on experiential learning. NCF-2023 emphasises learning science via active engagement of students with the world around them. It recommends nurturing the processes of science by exposing students to varied settings — the laboratory, classroom, and field — through a variety of approaches such as inquiry, discovery, didactic, and hands-on science. The position paper on science education spells out the need to develop adequate resources by a number of suggestions such as using science kits; low cost, no cost materials and equipment; alternate and improvised apparatus.

Many science educators have written about the significance of 'doing' science (Abrams, 2005). Tytler's, (2007, p31) "contention that science education needs to diversify its emphasis beyond focussing on canonical abstract ideas, and place an emphasis on the nature of science and the way it operates."

Laboratory-based learning has long been an integral part of activities have been used in many natural science disciplines, to teach students of diverse many age groups across spans in very different cultural and classroom contexts. However, researchers on laboratory use covers a wide range of teaching approaches, classroom settings, and learning environments. While this diversity provides valuable insights, it also makes it difficult to compare findings across studies. In the many studies and varied research settings important issues and variables intersect. However, there have been many substantive differences in the laboratory settings and in other variables reported. Therefore, to strengthen the rigour and cumulative value of research in science education, To develop research in the field, the science education community and especially the research community must be careful to provide clear descriptions of the educational context, including the characteristics of participating students, teachers, classrooms, and curricula. detailed descriptions of the participating students, teachers, classrooms, and curriculum contexts in research reports.

Lunetta et al. (2007), argues that the key variables that influence laboratory learning, should be documented in research reports. These include the intended learning objectives; the nature of instructional guidance provided by teachers and laboratory manuals (whether printed, electronic, or oral); the materials and equipment available; the design of laboratory activities; the quality and nature of teacher–student and student–student interactions; assessment expectations and practices as perceived by both students and teachers; students' laboratory reports; and teachers' preparation, pedagogical knowledge, attitudes, and instructional practices. Equally important is understanding students' perceptions of the purpose of laboratory activities, how they believe their performance will be evaluated, and the value that both students and teachers attribute to laboratory work. Studies should also report how much time students spend on laboratory activities, whether these activities are integrated into or separated from the rest of the science curriculum, whether investigations are short-term or long-term, and the size and roles of students within laboratory groups. Because laboratory settings vary considerably, detailed reporting of these contextual factors is essential for interpreting and comparing research findings. In addition, using clear and consistent technical terminology helps strengthen research and supports the use of findings in curriculum development, teaching, assessment, and education policy.

Many of the investigations that focussed on science have used quantitative, large-scale studies, or have selected a few schools with a low number of teachers.

Bajracharya (1986) studied the way science is taught at the secondary schools of Nepal. Some of the findings were that teachers used the lecture method to teach science. No practical work was incorporated in the curriculum, neither was it made relevant to the students' daily life. The teachers felt overburdened with work due overcrowded classrooms and had no time to prepare. Further no type of professional help was available to them from the school supervisors. Based on the findings Bajracharya concluded that the in-service training should focus on techniques of teaching, and learning to assemble apparatus from locally available material.

M.K. Morey (1990) studied the types of science instructional programmes of elementary schools to determine the preparation of teachers for teaching science and teacher attitudes to science and obstacles faced by them. Some of her findings showed that the type of in-service training received varied considerably and was inadequate, type of obstacles faced by teachers included lack of materials, lack of preparation time and time to teach. The role of the elementary science programme as perceived by the teachers was to demonstrate the use of science in the daily life of the child, reflect the effect of science on society and provide awareness of science careers. Half the number of teachers used only the textbook approach, while the remainder used the textbook in combination with other materials and methods. The findings also indicated that science teaching at elementary level remains dependent on textbooks despite research proving the efficacy of hands-on activity.

Stevens (1996) carried out a survey to determine which teaching methodologies and student activities were being used in classrooms and the amount of time being spent on the teaching of science in grades K-8 during the implementation of the 'Science Framework for California Public Schools' in San Diego, California, U.S.A. Some of the findings of the study were: (i) Hands-on-activities were the most often used method common to the primary, intermediate and middle grade clusters. (ii) Primary and intermediate grade teachers frequently used the integration of science with other subjects. (iii) Increasing tendency in the use of worksheets from primary to middle grades.

Laboratory work is unique to science education as a method of learning. It allows for actual participation and involvement of students in the processes of science. It thus promotes the development of conceptual understanding, process skills, as well as learning to investigate. Initially, laboratory activities were used to reinforce or verify what was learnt in the classroom.

However, when emphasis shifted to development of process skills the content was sacrificed in favour of the laboratory. Schwab (1964) felt that laboratory work should lead rather than follow classroom teaching. Tamir (1976) gives four major rationales for using the laboratory in science teaching: (1) Science involves highly complex and abstract subject matter that students find difficult to grasp without concrete objects and opportunities to manipulate, (2) laboratory work gives students a chance to participate and develop an appreciation for the methods and spirit of science, (3) development of many practical skills occurs, (4) the enjoyment of activities leads students to become motivated in learning science. Collette and Chiappetta (1984) describe five types of laboratory approaches. These are verification and deduction; induction; science process-oriented, technical skill-oriented; and exploration.

The deductive approach is to either illustrate examples of science learnt in classrooms or verify certain principles, laws or concepts. The inductive laboratory allows students to first experience instances of a concept before it is taught. The science process-oriented laboratory teaches students about how to investigate. Collette and Chiappetta (1984) include teaching the process skills specifically in this kind of laboratory method. The skills include – observing, classifying, learning to hypothesize etc. Thus, the focus of the laboratory exercise is teaching specific skills and channelizing the thinking process. The technical skills-oriented laboratory emphasizes the psychomotor skills such as measuring, focusing in microscopy, etc. which are some basic science laboratory techniques. The exploratory laboratory allows students complete freedom to explore and test their ideas.

The different laboratory emphases would lead to different outcomes such as – development of skill and verification or building up knowledge. However, in all cases, the students must be prepared to benefit from laboratory experiences as well as make maximum utilization of the available resources. This includes orienting students to the laboratory activity, giving directions and connecting what students have learnt or will learn in the classroom with the laboratory. The laboratory is also a place where students try and test their theories and are allowed to make mistakes as well as learn from them.

The guidelines of science education for the upper primary (NCERT, 1986) give seven dimensions of the goals of science education in terms of expected competencies. The third and seventh dimensions are associated with the processes of science. The third dimension clearly states "At the end of the Upper Primary Stage, the child is capable of using the process of science in solving problems, making decisions and furthering his own understanding of the universe." NCERT (1986) identifies 13 process skills in science. These are defined as follows:

1. Classifying: a systematic procedure used to impose order on collection of objects or events, on the basis of set criteria.
2. Communication**:** conveying information by various modes (oral, written, pictorial, using tables, bar graphs, pictographs).
3. Controlling Variables**:** identification and management of probable factors that may influence a situation or any event/experiment.
4. Formulating models: devising action mechanism, scheme or structure which will act or perform as if it were a specific real object or event.
5. Hypothesizing: stating a tentative generalization that may be used to explain a relatively large number of events but which is subject to testing.
6. Inferring: drawing simple conclusions on the basis of information and experience.
7. Interpreting data: to find a pattern or meaning inherent to a collection of data, leads to stating a generalization.
8. Measuring: using instrument(s) to estimate quantitative values associated with characteristics of objects or events.
9. Observing: using senses to obtain information.
10. Performing experiments: doing/seeing data gathering operations which provide basis for answering a question.
11. Questioning: to raise doubt on the basis of perception of the discrepancy between what is observed and what is known.
12. Using numbers: the technique of using number systems to express ideas, observations, relationships, etc. often as a complement to the use of words.
13. Using space-time relationship: the description of spatial relationships and their changes with time.

The seventh dimension of the goals of science education (NCERT, 1986) states, "At the end of the upper primary stage, the child develops skills of manipulating the following equipment." These include – metre stick/measuring tape, thermometer, graduated cylinder, physical balance, watch/stop clock, screw driver, changing fuse wire, maintaining and cleaning a bicycle, etc.

It is absolutely clear from these two dimensions (the third and seventh) mentioned above, that laboratory experience (hands on) is a significant aspect of learning science. The guidelines of NCERT (1986) have also clearly indicated some of the specific topics, grade-wise where and when a particular process skill is to be emphasized.

Simultaneously and in apparent contrast, the NCERT (1986) document comments "the syllabus for the upper primary school does not suggest a good number of experiments to be performed by pupils. Instead, the teacher would perform the experiments and demonstrate the methods and the results of such experiments.

In India science is a compulsory subject till Class X, and the National Curriculum Framework and policy documents consistently emphasise the importance of developing scientific knowledge, inquiry skills, and scientific attitudes. The Position Paper on Teaching of Science (NCERT, 2006) identifies one of the primary aims of science education "to acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge.". One of the aims of Science Education at school level is to "acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge" (Position Paper on Teaching of Science, NCERT, 2006). Achieving this goal requires science curricula and classroom practices that provide students with opportunities to investigate, question, experiment, and construct scientific understanding through meaningful learning experiences.

It implies that curriculum, classroom transaction, and learning spaces within the school setting should focus on creating opportunities for learners to innovate and verify the given facts and theories and be scientifically literate. The concept of scientific literacy has evolved since it was first introduced in the late 1950s and is now widely recognised as a central objective of science education worldwide. Broadly, a scientifically literate person possesses the basic knowledge of scientific concepts, has necessary skills and scientific attitude to use science and technology in an informed and meaningful manner.

RESEARCH DESIGN

Objectives

1. To explore the activities that take place in science in a cross-section of schools in Delhi.

2. To investigate the relationship between views of the teachers and their use of science activities in the classroom.

I wanted to understand how teachers used activities while teaching science. I wanted to comprehend the conscious deliberation, decisions that the teacher may need to make from time to time, regarding the teaching and learning of science; to perceive their given beliefs and constraints. It is for these reasons that I selected to concentrate mainly on the science teachers to gain an insight into the way they operated within the context of the school. I directed my attention to observe a teacher's transaction of science lessons and conduct interviews to gain insights into the teacher's understanding about science and science education. The method of microethnography (Erickson, 1986) was chosen as it allowed me greater access in multiple classroom situations and a chance to collect and analyse data without apriori theories.

Observations by the researcher may be construed in different ways and thus it is imperative that the researcher's own beliefs are stated as a necessary part of the study. By profession I am a teacher educator. My academic post-graduate degrees in science and education, as well as my directed reading had made the field of science education a familiar one; in fact, it had helped defining the field for me. I had to be conscious to not focus on the flaws in planning and transaction of the science lesson in progress.

The initial visit to the school included meeting the principals The next few visits were used to introduce myself to the science faculty and noting timetables, location of classrooms and laboratories. I spent some time explaining to teachers, the purpose of my study, assuring minimal interference in their daily routine and guaranteeing confidentiality. This opportunity was also used to partially get to know the background characteristics of the teachers – name, qualifications, years of experience, interests, etc.

The following techniques were used by me:

Classroom observation in the form of records as the teacher transacted the science lesson.

A semi-structured interview of the teacher.

I chose to observe each teacher for four to six lessons. The fact that I am middle aged and older than some of the teachers required much time and patience on my part to get them to accept me as a researcher. Likewise, students also varied in their responses, to the extent that only two teachers commented on their changed behaviour owing to my presence.

The semi-structured interview is more flexible since it provides an opportunity to the researcher to probe and expand the respondent's answers. One needs to establish rapport and empathy between the interviewer and interviewee.

While presenting the data, I have used italics if direct quotes have been used. In the case of teacher interviews, these have been followed or preceded by the name of the teacher. Where I have presented interactions, I have used the symbols 'T' for teacher, 'S' for student and 'M' for my comments. In the instances where more than one student has responded I have arranged them as S1, S2, ….

Sample

The present study focussed on the upper primary grades (VI-VIII). These constitute a unit that is neither at the beginning nor towards the end in school education. Sampling was carried out on three types of schools categorised on the basis of their fee structure; low fee (LF), medium fee (MF) and high fee (HF). (See table 1).

A total of 24 teachers were observed over a period of 6 months (See table 2). Each teacher was observed 4-6 times. Pseudonyms have been used for the names of the schools and the teachers. Most of the teachers I observed were women. This was not by choice, but dictated by the field situation. All the teachers had graduate degrees in science and edocation. Some also had a post-graduate degree in science. Pseudonyms have been used for the names of the schools and the teachers. Most of the teachers I observed were women. This was not by choice, but dictated by the field situation.

Table 1. Fee levied per month as the basis for categorization of schools

	Low Fee (LF)	Medium Fee (MF)	High Fee (HF)
Total Fees per month	10-20	2,000-10,000	12,000 onwards
Uniform provided	Yes	No	No
Books provided	Yes	No	No
Textbook published	NCERT	NCERT	NCERT
Medium of Instruction	Hindi	English	English

Table 2. The number of teachers observed in the three categories of schools

Category of schools	Number of schools	Number of teachers
Low fee	3	7
Medium fee	3	9
High fee	3	8
Total	9	24

FINDINGS

The aim of the study was to observe the types of activities that took place in the middle school science lesson. What are the kinds of activities that take place in the middle school science classrooms? Here the word 'activity' includes experiments conducted, demonstrations, paper-pencil activities and even observation of specimens and in one instance, listening to an audiotape. My observations are more focussed on the teacher and thus include the instructions and the way the science activity is conducted. I have also had an opportunity to observe how a teacher inducts students into the working of the laboratory.

Activities were carried out primarily to verify theory, or to provide concrete examples to enable the student to learn the concept. The students were not trusted to make fresh observations in science; even these were to be copied from the textbook or a laboratory manual. The focus of the activity lay in getting accurate results, and not on development of any skill, nor the excitement of exploration. In one incident students were asked to observe a preparation showing the epidermal cells in the onion peel. However, they were required to draw the figure from the manual, which showed the electron microscopic structure of the cell. The students could not relate their own observations with the figure in the book.

The joy in doing science and the excitement of exploring and experimenting was rarely observed. Only a very small number of teachers displayed verbal enthusiasm during an activity. The 'introduction' of students to the laboratory was usually peppered with admonitions to students such as to behave properly, not to touch and move any set-up or apparatus but only copy down the written or printed information.

It is the HF schools which had functional laboratories for the middle grades. When students enter the sixth grade, one of the special learning spaces is the 'laboratory'.

Induction into the laboratory

Early in the year, routines and controls are usually established to enable smooth functioning of the lesson. A teacher usually described what she did not expect students to be "doing in her class". Many teachers talked about establishing and maintaining routines without giving any explanations or reasons. The teachers thereby set up acceptable behaviour patterns of students.

One of the control measures was preventive in nature. This was found frequently in instances where the students were expected to do something different from the usual routine class work. The examples given below highlight the control exerted on students.

As students enter the laboratory, they see a number of charts, items of equipment, long tables, sinks, strange specimens, an array of bottles containing solids and liquids, burner, stands etc. They also smell weird substances. It is like a whole new strange world. The students become excited. I imagined that an introduction into all of this and initiation into the strange rites of the scientist, motivating students to satisfy curiosity, 'do' science and explore the various phenomena around them would be exciting. Yet it was not to be – introduction into these laboratories ranged from inducing boredom to fear of the rules and regulations, the do's and don'ts, both attitudes geared to suppress children's interest.

The following examples are of the first day spent in the laboratory by middle school students in a few schools. This is their initiation into 'practicals'.

As students file into the rows of stools set up for them, they find on the demonstration table in front of them, a compound and a dissecting microscope. Behind the teacher is a large chart showing the labelled details of the two instruments. The next two periods (about 40 minutes) are taken up by the teacher dictating the parts and uses of the two microscopes, by reading out from a practical file of a student from a previous year. While reading out the file the teacher holds the microscope in her hand and points out the corresponding part.

At the end of the lesson, the students are asked to draw the relevant diagrams from the laboratory manual. There is no better way of killing curiosity and develop a sense of boredom about science! Instead of going into so much detail, a drop of water from a pond put under a cover glass on a glass side and observed under the compound microscope by each student would have been dramatic! Likewise, a piece of skin or leaf enlarged under the dissecting microscope would have invoked great delight and wonder. Not much has been written about the excitement of 'science', yet it is this that is likely to produce maximum motivation to learn science and to connect it with the life of the learner.

In another school, laboratory classes were started with the teacher showing an array of glassware such as beakers, flasks, burettes, pipettes, measuring cylinders, funnels one by one, alongside description. A clear and stern announcement was: "*You are not to touch any of these*". The students were then asked to note down their names from the laboratory manuals and draw the appropriate figures.

The next is an example from Bharat School. The students came into the laboratory in great excitement; this was their first laboratory class.

T: *Class VI - Stand outside and come in roll number wise. Come and sit inside according to the table and roll number.* (She calls out roll numbers one by one and allots the students, seats).

T: *Now once you are in lab please maintain discipline. Keep quiet. Since you are coming first time let me give you certain instructions. You must bring your lab manuals every time. If you are without lab manual you will not be allowed to work. Bring your own instruments and* *pencils with you. Where you are sitting today will be your permanent seats. Put your stools* (the wooden stools) *back under the tables. Anyone not doing it will be severely punished.*

Here an initiation into science is through the use of preventive punitive measures.

Function of Activities

This type of a beginning is an indication of what is to follow. As part of my fieldwork, I carried out interviews of science teachers and heads of the science departments. I also sat in some of the departmental meetings. The rationale that emerged is that the activities are planned according to the needs of the content. Thus, the knowledge aspect of science is the focus for laboratory exercises. Nowhere was any emphasis laid on how a process skill is to be learnt. None of the teachers I interviewed had read anything about 'process skills'. All over the world, the focus of science has shifted from the initial emphasis on content to a focus on the process of science to integrate the two. The current view of science education is the intimate relation between science and society via the curriculum. This point of view has also been upheld by the NCERT (Ganguly, 1991). The middle school teaching still focuses on content, and the laboratory is just a means of verification. The high fee schools use laboratory manuals, either prepared by the teachers themselves or purchased readymade. Each student was required to buy a copy. For any activity that was carried out, the students were required to copy out the corresponding pages in their practical files.

Of the schools I observed, it was only in the HF schools, that laboratory and other activity classes were observed for the middle grades. Among the low fee schools, activities were observed only in one case. In the government and aided schools, my sample also included observations in the IX grade specially to observe the laboratory classes. Not all schools I visited had laboratory classes even at the ninth grade.

In the HF departmental meetings were held where decisions were taken on the methods of teaching and conducting activities. The senior teachers handled most of the resolutions; the role of the novice teacher was that of a silent spectator. In most of these schools, each practical class was conducted simultaneously by two teachers – a senior and a junior. The senior teacher gave instructions and planned the activity while the junior teacher helped and learnt the ropes. This procedure could be advantageous for inducting a novice teacher as an apperentice or a fallout; to perpetuate the traditional, theoretical way to conducting a practical class. This is a situation where the institution can step in and bring out the significance of science by doing.

For most LF school teachers, doing activities in science was not as important as the systematic drilling of scientific knowledge. The teachers spoke at length about the constraints they faced such as lack of funds, resources, red tapism, lack of time and poor ability of students.

Anju: *When I joined the school, I was interested in carrying out activities. I needed* H_2SO_4 (sulphuric acid*) so I wanted to order it. I had to order in triplicate … their quotations were sent, then more delay … finally more than four months went by … I lost interest.*

Bela: *They* (teacher educators from the Dept of Education) *want us to carry out activities, but there is no point. These students are not interested. I spend so much time reteaching and revising the same topics. There is no time to carry out activities.*

She is one of those who dictates activities from a previous year's practical file for class IX students; asks students to copy down her dictation in their practical file.

Rana: *The senior teachers* (he means the post-graduate teachers who teach classes IX-XII) *do not give us chemicals easily; we have to request them many times, afterwards we just give up.*

The teachers' belief about science and science education also emphasizes science as a body of knowledge, thus further reducing the incentive to use activities for learning. Only two teachers of the LF schools conducted activity lessons, both were in schools which had an association with the Department of Education.

Both these teachers were convinced that learning was enhanced when students performed an activity, or at least observed when the teacher demonstrated it. Isha is the only upper primary science teacher in the University Model School. She had the complete support of the headmistress who was herself a science graduate. She admitted that it took her a lot of time and effort to plan for activities, but each year it became simpler.

The lack of support made it more difficult for Saroj, and she requested me not to share my observations with other teachers in the school for fear of being jeered by her colleagues. She chose to perform only those activities which did not require taking materials from the rudimentary science laboratory of the school. Her reasons were more based on surviving in the school environment though personally she was convinced about the significance of learning by doing and applied it to an extent in the classroom.

Type of Activities

I have classified the activities I observed into three groups. These are: '**actual activities**, '**semi-activities**' and '**theoretical activities'**, depending on the participation and involvement of the students themselves. In all the cases, the role of the teacher is a dominant one - she decides the activity, the method to follow, and even the conclusion. The role of the student is reduced to copying written and spoken instructions and manipulating to get the right results. No kind of intellectual stimulation is given or perceived and the initial excitement of laboratory days dissipates into boredom.

The actual activity

In the exercise the teacher instructs and the students carry out the activity. The instructions given vary in form – verbal, dictated notes, instructions written on the blackboard or by the teacher demonstrating the technique. The examples given below highlight this type of activity and the way it was conducted. The teacher demonstrates to groups of five students how to study parts of a flower.

Shikha drew a graph on the blackboard over which she sketched the outline of a leaf. She then demonstrated to students how to calculate the surface area of the leaf, by counting the number of complete squares and adding these. Next, the students were asked to find out the surface area of the leaf they had brought to the class. This seemed like a worthwhile activity. However, the next day Shikha asked the students to find out the surface area of the palm of their hand (another irregular surface). The entire exercise was demonstrated on the blackboard once again before students were allowed to actually carry out the activity. It seemed as though the teacher felt that the students were unable to transfer knowledge gained from one activity to the next. During the interview Shikha said: "*Well ... few would be able to do correctly, some won't know and many will make mistakes; so, I feel it is better to show them (pause) it will save time to correct"*.

The activity again focuses on 'correct answers'. While the child performs the activity, the real test is how accurate she has been. A closer analysis of an activity in the context of the content and the manner in which it is conducted creates doubts regarding the worth of the activities in a science classroom.

The class VI textbook of science includes an exercise whereby the width of a single coin is estimated by stacking a number of coins, measuring the total width and dividing it by the total number of coins. The activity described below is a similar exercise and could have been performed in the classroom. Instead, it took place in the laboratory one week, two weeks or three weeks subsequently depending upon the grade and section and its turn to use the laboratory according to the time table.

T: *Suppose we want to find out average age of class what will we do?*

S1: *Add everyone's age and divide by number of students.*

T: *Suppose we want to find out diameter of thread. Who has brought thread*? (many hands up).

T: *Will we be able to do so? Scientific way will be to do by making turns on a rod of thread. I will do 10; you should do 30 or 50 at least.* (Teacher demonstrates how she winds the thread around a pencil).

T: *You see that length of these turns is 0.5 cm so length of 10 turns is equal to 0.5 cm. So how much should be length of 1 turn.*

No response.

T: *Suppose 10 bananas for Rs 5. So, 1 banana for how much? Likewise, 10 turn = 0.5 cm; so, 1 turn = 0.5/10 = 0.05 cm.* (this is done on the blackboard).

1 turn means diameter only. So, it means you have calculated diameter. Now I have done this experiment in front of you. You should also do it but with 30, 40 or 50 turns."

T: *Before you take readings, you should show me first. There should be no gaps and no overlaps.*

The students who had gathered near the teacher's table returned to their seats to carry out the work as the teacher supervised. No explanation was provided by the teacher or sought by a student as to why the teacher wound the thread only 10 times yet required students to do so 30, 40, 50 times.

Towards the end of the lesson, the focus and interest of students as they performed the activity was to see how many turns of the thread they could make. Again, this could have lent itself to developing an understanding about the increase in number leading to greater accuracy in measurement. Instead, the students were dissuaded from doing so. An exciting possibility of hypothesizing, predicting results and drawing conclusions meant a lot of fun but ended up as a mundane reality. The science teacher seems to have lost the enthusiasm in science.

Actual activities retain a recipe following tendency with no possibilities for a student to explore. The teacher and the laboratory manual know best was the message that came through, curtailing all thought about the various possibilities in an activity. The teachers gave a variety of answers when they were asked "*Could the students devise ways of carrying out the activity or suggest changes?"*

Shikha: (a long pause*) But this is the correct method to do it.*

Mita: *How would they* (the students) *know?*

Mugdha: (righteously*) Not for these types of activities. But we give them a 10 marks project where they can select what they want to do.*

Prema: *I never thought of it.*

Mansi: (silence).

I also became aware as I spent more time in the school, that the activities, especially those which were to be held in the laboratory were sequentially planned to suit the timetable and progression of content. The activity itself either preceded or followed content (theory taught). Thus, there was a scope to develop the activity as an inductive or a deductive one. The activity was instead carried out merely as an exercise to be performed, or syllabus to be covered.

Demonstrations and semi-activities

It is not always possible for a student to carry out an activity. The demonstration is a chance to see the processes of science. The teachers I observed used demonstrations for three types of purpose. The first is while teaching a concept. In a few instances, the teacher brought materials to the classroom and the demonstration was used alongside theory.

Kalpana used a separating funnel to demonstrate how a mixture of oil and water may be separated, while teaching the separation of mixtures. This type of demonstration was primarily the initiative of the teacher. I observed that in the Police Academy School where different teachers handled different sections of the same grade, all sections were not shown the demonstrations. During the interview Kalpana indicated the importance she gave to a student being able to view a process which enabled her to understand the concept better.

The second purpose of a demonstration is when expensive equipment or strong chemicals are to be used. One of the science activities planned in Deshmukh Bhai School is the demonstration of a number of chemical reactions. Here Vidhu first drew a table on the blackboard and as the reactions were shown, the table was filled up. The teacher intentionally chose reactions where a colour change or a temperature change takes place. According to Vidhu, this makes the activity more exciting. As she proceeds with the demonstration, the students are asked to describe the reaction taking place and categorize it as a physical or chemical change.

In IPS, the Archimedes' principle was demonstrated by the teacher using an overflow meter. In this instance, the student is required to write the demonstration as an experiment and followed the pattern of writing the aim, materials required, theory, method followed and conclusions. Thus, a science activity, performed by a student is not distinguished from one that is demonstrated by the teacher. This reiterates the emphasis given to the product and not the process of learning science.

A third purpose of a demonstration is to highlight the instructions given before students carry out an activity. Mohini demonstrated how to open a dry cell to view the inner structure. She demonstrated the first step; the students observed and did likewise, then the next step and so on.

T: (giving the explanation) *Earlier the coin in the cup was in air* (an ambiguous statement) *when water was poured, the medium changed from rare to dense.*

A few times, the science teachers have showed specimens and slides. The students queue up to view these. Unfortunately, they are then asked to draw what they have observed by referring to the textbook or laboratory manual rather than from their observations.

Theoretical Activity

The type of activity or non-activity observed most often is the one where the entire process is read out (from the textbook, laboratory manual or a previous year's practical file). The students are expected to copy these into their practical files. A slight variation may occur when the teacher explains the activity on the blackboard with the help of diagrams. In many cases (especially in the upper primary classes) the students are also not required to write these down as activities.

In one instance the teacher Mina was explaining "refraction". The explanation took place in English and the language used by the teacher is reproduced verbatim.

T: *A similar phenomenon is where coin is in a beaker of water* (She draws 'A' on the black blackboard). (see Fig. 6.2, part A)

T: *You will observe coin has been raised.*

T: *For observer where rays meet if backward, there coin is.* (see Fig. 6.2, part B)

S_1: *Ma'am why ray goes backwards*?

T: *If we go backwards, position changes more*. (She now repeats the diagram Fig. 6.2, part C).

T: *If we see through beaker what will happen? It will be normal.*

T: *Why position of coin will change?* (Now the teacher goes from table to table explaining to smaller groups, but they find it difficult to understand.)

T: (giving the explanation) *Earlier the coin in the cup was in air* (an ambiguous statement) *when water was poured, the medium changed from rare to dense.*

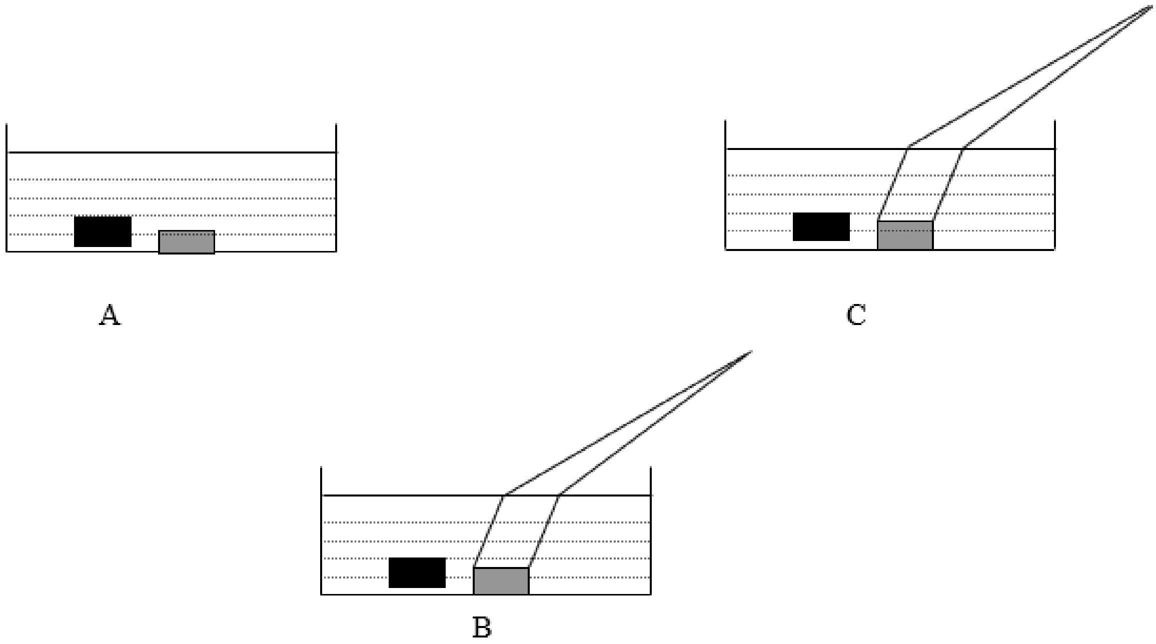

Figure 1: The illustration drawn on the blackboard to explain the concept of refraction

In this instance concept development would have been made easier if the teacher had actually demonstrated the apparent shift in the position of the coin or if the students had themselves carried out the activity. The materials required to carry out the activity are: a basin, a coin and water, all of which are easily available. The teacher spent over twenty minutes trying to explain the concept in smaller groups. It obviously took more time to explain the concept theoretically, than it would have taken to demonstrate it. The school in which I observed the incident claims to be an 'advanced' school, where computer-aided learning takes place. This is clearly a case of a school well stocked with modern instruments and technology but poor in imparting basic concepts with simple tools.

The same example of a theoretical activity on refraction was observed in Lakshmi Vilas. Here, even a diagram was not drawn to illustrate the point.

T: *Put a coin in a cup; move slightly backwards till the coin can not be seen. Pour water into the cup and the coin is visible again*. Why?

S_1: *it will get light*

S_2: *due to shadow*

T: *What connection does it have with light?* (Even though the term for the topic 'Refraction' in Hindi is 'prakaash apvartan' or "light refraction").

I observed teachers on many occasions dictating activities to students to fill in their activity files, when the activity had not been actually done (AC-B4, MC-G3). Many activities are easy to demonstrate and require very simple equipment.

'Theoretical Activities' were carried out easily by placing the responsibility of doing the activity on the student. The following example calls attention to the adroitness with which the teacher shifted the onus on to the student.

Even for teaching a topic such as zones of a flame, the usual method of reading out the text aloud, followed by the teacher paraphrasing it, was maintained. No candle was lit; Bela asked the students to carefully see the zones illustrated in the textbook. Next, she read out the two activities noted below and asked the students to try these at home:

1. *Place a glass tumbler inverted over a lighted candle. See what happens*.
2. *Place 3 sticks at the three different zones of the flame of a candle. Find out which will light up first.*

When Bela inquired the next day, she found that while few students had done the first activity, they could not attempt the second as *"they could not find sticks"* to which the teacher replied *"Could you not take three twigs from a shrub growing outside your house?"*

It is quite evident that in this instance neither the teacher, nor the students thought about using the stems of matchsticks (removing the head) even though the teacher kept using the word 'tiliyan', (Hindi equivalent of matchsticks). Bela could have easily demonstrated this exercise herself. Instead, she complained to me "*Students do not have the sense to do the experiment using sticks*." Bela has a B.Ed. degree and many years of experience. She has undergone an intensive in-service programme conducted by the Department of Education, University of Delhi where the importance of demonstrations using locally available materials has been a theme. Bela says, "*We cannot do so in class because of less time, how will we complete the syllabus.*" Thus, it is the mindset that needs to be addressed, both during pre-service and in-service programmes. Unless the teacher commits herself to "show and explain" no change would occur. The teacher would continue to offer excuse such as:

Anita, Swadesh: *"I don't have access to resources*"

Rana, Thukral: *"The students don't have interest*" (Rana, Thukral)

Bela, Giri, Pushpa *"I have to complete the syllabus*"

Bela*: "It takes too much time*"

In one instance it was the students who suggested 'doing' the activity but the Sudip brushed it off and exerted his authority to determine the 'right' way of doing the activity.

T: *Do this activity at home. Keep a tumbler, put a cardboard piece on top and place a coin on top of that. If you suddenly move the cardboard, the coin will fall. Why?*

S_1: *If we had* (materials) *in class we could have done it.*

S_2: (gives a bottle cap)

T: *We cannot do with this*

The only materials required here were a glass tumbler, a coin and a piece of cardboard. However, the responsibility to perform the activity shifts to the student.

Importance of Text and the Pattern of Writing

The text (laboratory manuals, textbooks) assumes undue significance for doing activities in science. The activity has to be performed in a pre-set fashion using only the suggested apparatus and also written in the way prescribed.

T: *So here the colour of the product is blue* (while demonstrating a chemical reaction)

S_1: *Ma'am it looks more like green.*

T: *Okay then write blue-green, actually better to write blue*.

(here 'blue' is the expected answer)

While drawing, the student is encouraged to look into the manual or the textbook instead of directly observing the specimen, apparatus, or even glassware. The reasons for this are varied.

John: "It provides uniformity. Everyone has the same text and drawing."

Premila: "*There is accuracy if they draw from the manual*."

Shikha: "*They* (the students) *are not competent to observe properly. They may miss certain points."*

Sukanya: *"Our microscopes are not so good. The students too, make mistakes."*

Ultimately the focus is on 'correctly' writing the activity and making an 'accurate' drawing - an extension of the 'right answer' framework.

Students belonging to aided or government schools were perhaps unable to buy laboratory manuals. Therefore, the teacher dictated the entire activity copied by students in their practical files, often without actually doing the exercise.

During one observation the teacher dictated outlines of three experiments. She read out the activity from the file of a 'good' student of the previous year so that the order and sentence construction remained identical. The teacher admonished the students who came without files. As a punishment they were asked to sit on the floor and copy the instructions. After the 'practical' was recorded, including noting the conclusions Bela instructed the students to copy the diagrams from a textbook. In the meantime, she started to correct students' written work (practicals). The incident brought out the dichotomy of the system. While students were punished for minor infringement of rules, the teachers escaped accountability for their actions or inaction.

In most schools the students were instructed to write out the practical work in a set format that included the aim, materials required, theory, method, conclusion and precautions. The notable exceptions were the Deshmukh Bhai and Green Valley schools, which encourage individual styles of doing and reporting the exercises.

'Doing' science on paper is sheer mockery. But the teachers spoke eloquently and authoritatively during the interview on the scientific method identifying a problem, making observations, carrying out the experiment, recording and drawing conclusions.

Observer Effect

John informed me that he was going to show demonstrations to class VII. In the laboratory, the teacher gave me a place to sit next to the demonstration table facing the students. In the next 40 minutes John conducted seven demonstrations.

Later in the day, when I queried what had been demonstrated in the class, none of the students could explain any of the seven demonstrations they had viewed. A few other students recalled one, two or three demonstrations.

A demonstration in science teaching has multiple functions – to initiate or guide thinking, illustrate a principle or concept, to review or, answer a question. In this instance, the purpose of demonstration was unclear, as also the procedure. What emerged from a long informal chat with the teacher in the staff room was his desire to try out demonstrations – a first, for this teacher in my presence.

When I compare the curriculum management of this school with that of Deshmukh Bhai School, where teachers construct activities co-operatively, the importance of a supportive environment becomes apparent. Perhaps given encouragement, stimulus and a little help, John might have also succeeded in using demonstrations as a part of his teaching repertoire. It did emerge during my conversation with him that my presence and observations motivated John to think about the long-forgotten goals of the pedagogy of science. The above is an inkling of how teaching becomes a routine job for a teacher and just the introduction of an observer gives him an impetus to try out and reconstruct pedagogy.

It is the only the high-fee schools which had functional laboratories for the middle grades. However, only in one of these did the activities go beyond verification.

For most government school teachers, doing activities in science was not as important as the systematic drilling of scientific knowledge. The teachers spoke at length about the constraints they faced such as lack of funds, resources, red tapism, lack of time and poor ability of students. However, the textbooks contain activities that can be performed using easily available material. However, two teachers were different, activities were carried out and demonstrations performed in their classes.

The middle-fee schools fell somewhere in between. Here the ideology of the school or the personl views of the teacher played a role.

DISCUSSION AND CONCLUSION

A study by Abrams (2005) examined whether practical work in science resulted in affective outcomes. The results indicated that the majority of students had high levels of short-term situational engagement in science. However, practical work was found to produce no long-term gains in generating engagement in science. Most students viewed practical work as a opportune break from other teaching and learning approaches. Some of this lack of long-term engagement may be the result of the nature of practical work in schools. For example, Abrams and Millar (2008) suggest that much practical work in science classrooms seems to be preoccupied with pupils being able to "produce the intended phenomenon" (p. 1955). Students might therefore be able to recall the experiment and what happened, but be unable to explain why they got the results they did and what scientific ideas were behind the exercise. Practical exercises and scientific theory were not always linked together effectively. In the present research, some teachers did carry out activities, by and large, these focused on either the end product or/and followed a recipe format. Very rarely did the teacher give opportunities to reflect on the 'how' and 'why' of the phenomena.

While science laboratories have been given an important role in science education, research has not shown significant change in conceptual learning by students. Hodson (1990) disparaged laboratory work as ineffective as the intention is often unclear. Tobin (1990) wrote that: "Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (p. 405). He indicated the need to give students opportunities to construct their knowledge of scientific concepts by being able to themselves manipulate materials and apparatus.

NCFSE-2023 advocates that activities in science can take place in classrooms, science laboratories or even in the field. It suggests "setting up of "Tinkering laboratories" where students can 'play' with simple scientific materials and equipment independently be set up in any room within the school." This aspect should be taken up in the teacher education programmes, where the interns are provided with opportunities to do hands-on-activities. The observations of science classes and interviews with the teachers indicates the long-time support required to empower them to provide opportunities to their students to do activities.

It is important to take into context the workload of the teacher. Most science teachers of the middle school grades have 32-38 periods a week that is six or seven classes out of a total of 8 in a single day. The teacher moves from one class room to another. Thus, usually every half-hour, the teacher shifts her locale to a different classroom, to another set of 35-60 students, usually to a different topic and she does this a minimum of six times a day and she does it alone. In addition, she has other duties such as having overall charge of the class, lab-in-charge, as a coordinator for myriad co-curricular activities. The heavy workload is likely to use the time and energy to conduct activities, the teacher here would require support, time and space if they are expected to provide for experiential learning.

A few schools give the teacher time and space to plan, to study, or to organize teaching. One school provides each teacher with one period each for library and resource room for reading. Two other schools have identified specific periods in a week for departmental meetings.

The study demonstrates that although national curriculum policies have consistently advocated learning science through experimentation, inquiry, and active engagement, classroom practices continue to be dominated by teacher-directed, verification-oriented activities. Science activities, where conducted, frequently emphasised obtaining predetermined results rather than encouraging observation, questioning, problem-solving, or independent investigation. Teachers' beliefs about science, together with structural constraints such as inadequate resources, excessive workloads, examination pressures, and limited institutional support, significantly influenced the quality and frequency of practical work.

The findings suggest that improving science education requires more than providing laboratories and equipment. Teachers need sustained professional development, opportunities for collaborative planning, and institutional support to design and implement meaningful hands-on learning experiences. Equally important is a shift from viewing practical work as an isolated classroom exercise to recognising it as a means of developing scientific thinking, curiosity, and problem-solving abilities. In line with the vision of the National Curriculum Framework (2023), science classrooms should provide opportunities for students to investigate, explore, and construct knowledge through active engagement with their surroundings. Strengthening these dimensions will contribute to the development of scientifically literate learners who are better equipped to apply scientific understanding in everyday life and to address the challenges of a rapidly changing society.

Focussing on the context of Indian culture is likely to create a better learning, based on traditional patterns. This aim has directed the school science education ‘Rika’ in Japan. According to Ogawa (1998) “Rika encourages pupils to (1) commune with Shizen (nature), (2) perform observations and experiments, (3) acquire the ability of problem solving, (4) acquire a feeling of loving Shizen, (5) understand natural things and phenomena and (6) acquire the scientific view and way of thinking” Ogawa opines that the objectives 2, 3, 5 and 6 are similar to those of learning science anywhere in the world. However, objectives 1 and 4 are distinctively Japanese elements of science education.

In the Japanese interpretation of the second objective, it is not necessary that the “activity ends in theoretical abstraction, for the Japanese students and teachers enjoying activities in and of themselves is a principle and appropriate aim” (Ogawa 1998). None of the western documents (or the ensuing Indian policies) referring to the aims, goals and objectives of science education have anything even remotely similar to the Japanese notion of enjoying and loving Shizen, as a rationale for science education. In India, Tagore brought out an appreciation of nature and highlighted the idea of the entire school communing with nature. It remained a cherished idea, which did not find a concrete shape in the education policies.

The earlier view that science is acultural is no longer considered true. The influence of constructivism, learners’ own ideas in science (misconceptions), and science studies has brought about an awareness of the importance of culture and the learner’s identity. It is therefore imperative to recognize and articulate an understanding of the type of science education that would be truly meaningful to Indian students. A cautionary note would be not to perpetuate the views of any one dominating group in India, which has a variation of people belonging to different cultures, regions, religions and languages. At the same time, it is necessary to recognize and appreciate indigenous ways of gathering knowledge and using it.

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