Learning Science in Classrooms, Nurturing Thinking Abilities

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Abstract

Science is a systematic process of understanding nature and the dynamic relationship between human and nature, and Science education aims to help learners understand this process by acquiring certain types of knowledge, skills and thinking abilities. It is imperative to investigate — are classrooms providing students opportunities to achieve the aims of Science education? The present study attempted to answer pertinent research questions — "What do teachers regard as the most important purpose of Science teaching? How does this understanding translate in classroom practices? How is Science teaching in classrooms aligned with the goals of Science education in 21st century?" The paper presents critical analysis of teaching-learning practices followed in the classrooms, and evaluates potential of these practices in fostering thinking abilities among students. Questionnaire based survey and focus group discussion were used to collect information from a sample of Science teachers. There is evidence that knowledge-transfer methods promoting rote memorisation are prevalent in most of the classrooms, whereas thinking abilities find the central place in educational policy documents of 21st century. Probably a strong linkage exists between the notion of Science as a body of knowledge and non-child-centric classroom practices. There was negligible indication of practices to stimulate students' thinking and inculcate scientific attitude. To accomplish the purpose of Science teaching at school level, classroom practices

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need to be radically changed in a manner that matches the way "scientists work and think". The paper also recommends and discusses some innovative teaching-learning practices and other system-related changes, as potential measures to improve the quality of Science learning.

Introduction

Role of school education has been crucial in enriching knowledge, developing skills, inculcating habits, and instilling right values among individuals and societies. It is believed that abilities developed during childhood play a major role in overcoming the hurdles and challenges in the real life ahead — personal, social or professional. It begins with deriving meaning from what we learn in our classrooms. Is it really happening within the education systems? Are citizens (global) able to draw relevant meaning of their learning and utilise their understanding to solve real life problems? About two decades ago, Howard Gardner had expressed a genuine concern in his famous book, *The Unschooled Mind*:

"... even students who have been well trained and who exhibit all the overt signs of success—faithful attendance at good schools, high grades and high test scores, accolades from their teachers—typically do not display an adequate understanding of the materials and concepts with which they have been working. Students who receive honor grades in college-level physics courses are frequently unable to solve basic problems and questions encountered in a form slightly different from that on which they have been formally instructed and tested..." (Gardner, 1995, 2011, p. 3).

Based on students' responses for a typical question from Physics, he further reiterated:

> "…….*Yet 70 per cent of college students who had completed a course in mechanics gave the same na*ïve *answer as untrained student..."* (Gardner, 1995, 2011, p. 3).

Gardner raises a very relevant question "Why are students not mastering what they ought to be learning?" The paper is an attempt to investigate this "why" by analysing how our school students are learning Science in their classrooms.

"What is the basic goal of Science education" is always the beginning point of such educational inquiry. Engagement with this question also necessitates exploring "what is Science all about". We have been reading in books or magazines and hearing at various fora that Science is an evolving and expanding body of knowledge derived from many investigations. The point that needs to be emphasised is that it is not just a body of knowledge, but also comprises a set of methods and practices that lead to knowledge generation (or, construction). Inquiry-based and problem-solving approaches form the heart of all scientific methods. Science is an activity of understanding the world we live in, through systematic observation and rigorous reasoning. It is about relating theories to the evidence using the body of scientific knowledge and practices, critically evaluating and challenging existing theories, and/or modifying them as per evidence. Aims of Science education have their foundation on this nature of Science. Teaching of Science is meaningful, only if it is in harmony with the nature of Science and aims of Science education.

At the juncture, when Science is expected to immensely contribute to the sustainable development of humanity, Science teachers, educators and academic leaders need to examine deliberately — "Do their classrooms and classroom practices reflect the objectives of Science education?" This would lead to exploring the strategies that have the potential to realise the goals of Science education.

Objectives and Methodology

The present study revolves around the focal issue — "***Does Science teaching in schools have the potential to develop scientific inquiry and thinking abilities among students?***"

The following research questions.

1. What do teachers regard as the most important purpose of Science teaching?
2. How does teachers' understanding translate into classroom practices?
3. How is Science teaching in classrooms aligned with the goals and the best practices of Science education?

Sample for the study consisted of 98 Science teachers from 36 different schools. Table 1 shows some basic characteristics of the surveyed population.

The required data was collected through a small focus group discussion, followed by administering a mixed type of questionnaire to individual respondents. For close ended items in the questionnaire, respondents were instructed to mark their responses on a rating scale of 1–5. These categories were mapped with frequencies of occurrence of events, to help respondents register their responses more objectively.

Table 1
Characteristics of Respondents

Gender		**Educational Qualification**		**Location**		**Classes Teaching**				**Medium of Teaching**	
Male	***Female***	***Graduate***	***Masters and above***	***Metro cities***	***Non-metro cities***	***Upto V***	***Upto VIII***	***Upto X***	***Upto XII***	***English***	***Hindi***
18	80	62	35	40	58	17	28	45	8	69	29

Following description was provided to ensure that each category is more likely to mean the same to different people.

1. (Very frequently) – in more than 75 per cent periods
2. (Frequently) – in 50 to 75 per cent periods
3. (Occasionally) – in 25 to 50 per cent periods
4. (Rarely) – in less than 25 per cent periods
5. Never

To address the third research question and relate findings to research and policy documents, review of research literature and major policy documents was done. Important Indian policy documents were the *National Education Policy and Plan of Action* (MHRD, 1985, 1992), the *National Curriculum Framework* and Position Papers by Focus Groups on Aims of Education and Teaching of Science (NCERT, 2005, 2006), *National Knowledge Commission Report* (NKC, 2009) and *India Science Report* (NCAER, 2005).

Findings

The major findings of the study have been presented under the following headings.

Top Five Purposes of Teaching Science in Schools

Figure 1 shows the top five responses of teachers about "the most important purpose of teaching Science in schools". It can be seen that according to 30 teachers, development of experimentation skills is the most significant purpose of Science teaching. This notion was followed by the understanding of scientific concepts and principles (23) and acquisition of knowledge (14), respectively. Responses like to develop abilities to apply scientific knowledge in everyday life, to develop thinking skills, and to make them better human beings altogether counted 15. Other responses were helping children to become scientists (2), doctors or engineers (5); getting admission in good colleges (3); getting well paid jobs (2).

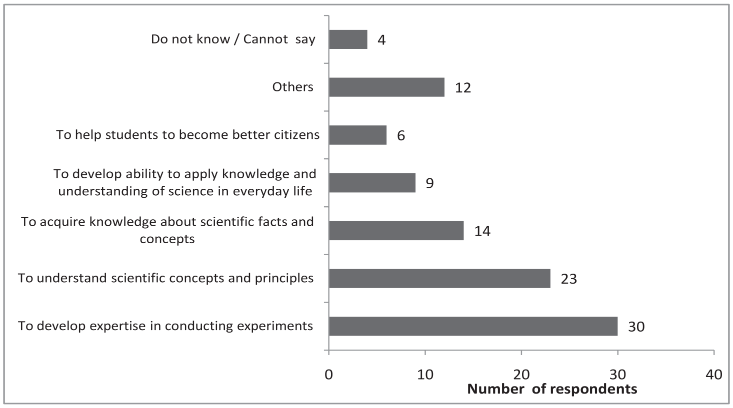

Figure1: Teachers' Responses about Purpose of Science Teaching

Frequency of Various Teaching Learning Practices in Classrooms

Science education leverages a variety of teaching methods, tools and classroom techniques to achieve its purpose. Questionnaire had a list of methods, along with others (specify), and teachers were requested to mark the method they used in the last academic session, on a scale of 1–5, based on quantifiable frequency. They were allowed to pick two or more methods. A large number of respondents selected more than one method, whereas 18 of them had selected more than five. Table 2 shows that textbook reading and traditional lecture (chalk-talk) method dominates in most of the Science classrooms. About 53 participants used textbook reading in their classrooms on more than 50 per cent occasions, whereas 50 respondents used lecture method with blackboard on more than 50 per cent occasions.

In classrooms of 19 teachers, demonstrations of scientific principles or practices were part of classroom teaching on less that 25 per cent occasions, whereas 79 teachers never used demonstration during classroom lectures. Use of charts, posters, models or audio-visual materials on about 25 per cent occasions was reported by 27 teachers. About 13 teachers marked use of experimentation method on rare occasions. Number of such teachers who never used audio-visual aids and experimentation method during teaching was 71 and 76, respectively.

Table 2
Frequency of Teaching Learning Practices in Science Classrooms

	Teaching-learning methods	**1**	**2**	**3**	**4**	**5**
1	Textbook reading	15	38	17	17	11
2	Lecture with blackboard	27	23	34	14	-
3	Lecture-cum-demonstration	-	-	-	19	79
4	Use of audio-visual aids	-	-	-	27	71
5	Experimentation	-	-	-	22	76
6	Project work	-	-	-	21	77
7	Inquiry methods	-	-	-	9	89
8	Other methods (<5)	-	-	-	13	85
		Number of respondents				

Note: *Twenty-one respondents had assigned projects to their students on rare occasions (less than 25 per cent times).*

Status of Questioning as Teaching Learning Method

Asking questions, noticing and observing have been considered as the basic abilities for scientific inquiry. It can be seen in Table 3 that 20 teachers used questions to involve students in thinking on various occasions. Nine teachers made effort to gather ideas of previous knowledge with the help of questions in more than 50 per cent classes. Seven teachers leveraged questioning as a trigger to build upon teaching learning in their classrooms.

Table 3 shows that most often, questions were used to test knowledge and award marks or grades. In classrooms of 15 teachers, questioning got a significant attention after completing the topic. It was also observed that questions were mostly confined to the textbooks, and were rarely drawn from real-life situations or addressed students' curiosity.

Table 3
Status of Questioning as a Teaching Method

	Aspects of questioning	1	2	3	4	5
1	**Use of questioning — why**					
	(a) as stimulus to engage students in questioning and thinking	-	4	7	9	78
	(b) to measure preconceptions among students	4	5	13	17	59
	(c) as tools to build upon the learning process	2	5	11	18	63
	(d) to revise and reinforce the learning	4	9	14	21	60
	(e) to test students' knowledge	11	20	51	16	-
	(f) to award marks to the students	15	28	55	-	-
2	**Use of questioning — when**					
	(a) before teaching any topic	6	8	15	15	54
	(b) after completing the topic	5	9	20	37	27
	(c) during teaching	3	8	12	23	55
3	**Use of questioning — source**					
	(a) The content in the textbook	59	35	4	-	-
	(b) Students' everyday life	2	7	10	17	62
	(c) Students' natural curiosity	-	-	6	8	74
		No. of respondents				

Aims and Practices of Science Teaching — in Policy and Education Research

In the context of 21st century, Hurd's two major aims of Science education, knowledge and enterprise can be best articulated as: (i) to impart knowledge, abilities and values that enable students to work in a specific local context, and (ii) to develop scientific attitude and temper that promotes thinking in a global perspective (Hurd, 1960). Fulfilment of these aims is crucial for sustainable growth and development of societies.

The nature of Science is neither universal nor stable (Lederman, 1992) and the same holds true for the aims of Science education. Evolution of scientific knowledge is most often driven by societal (or global), economic, political and cultural forces. With increasing role of Science and technology in everyday life, questions like "what is it that children should know?", "why they should know", and "how they should acquire and utilise their knowledge for individual and social well-being" are gaining much attention of social scientists.

In knowledge-and-intelligence-based-economies, Science education aims to enable and empower young minds solve problems of day-to-day life in a logical and meaningful manner; to promote well-being of individual(s) and societies. It is strongly believed that scientifically aware and literate citizens have the potential to bring about societal transformation. Engagement of students with scientifically-oriented questions is the most essential component of scientific inquiry and asking questions have been considered as the first and the most important scientific process in the Science framework for K-12 education by the National Research Council, US (NRC, 2012). At the same time, Science teaching must ensure to cultivate and sustain the joy, wonder and motivation of learning (NCERT, 2005).

Scientific inquiry has always been assigned a significant place in education policies. The Education Commission, 1964 highlighted the need for developing a spirit of scientific inquiry among students (NCERT, 1971). In 1976, spirit of scientific inquiry, temper and humanism was included in the Constitution as fundamental duties of all citizens. It was also endorsed by the *Programme of Action* (1992) for the *National Policy of Education, 1986* (MHRD, 1992). The Position Paper by the national focus group on teaching of Science (NCERT, 2006) also emphasised the need for inculcating scientific inquiry and temper among school children and stressed on a student-centric teaching learning process.

The Position Paper has stressed that aims of Science education should follow directly from the six criteria of validity for the curriculum, *viz.* cognitive validity, content validity, process validity, historical validity, environmental validity and ethical validity; with an emphasis on developing scientific temper (NCERT, 2006). Use of scientific methods, inquiry and problem-solving approaches of learning in secondary stage Science classrooms have been explicitly recommended by the focus group (NCERT, 2006).

Acknowledging the challenges and issues in achieving these aims, the Position Paper recommended major infrastructural and qualitative changes in Science teaching, so that the classroom practices are in sync with the notion of "learning to learn", "nurturing curiosity and creativity" and "building scientific temper". Pratt and Hackett (1998) suggested that students develop deeper understandings of Science concepts and critical thinking skills of learning Science by inquiry. A study by Hanauer (2006) reveals how under the heading of scientific inquiry a multi-modal structure of oral, written, visual and physical forms of communication direct students to the required and predefined results.

Feynman (1995) characterised the scientific method in three words — observation, reason and experiment. Memorising the content given in textbooks, in order to help students score better in examinations neither relates to the nature of Science nor to the aims of Science education. Science is also not about reproducing the steps of an experiment, as emerged during the investigation. Highly-structured experimentation techniques lay little emphasis on thinking skills and scientific attitude.

A huge visible gap exists between the aims, policy perspective and teaching-learning practices in the classrooms. Experiences narrate that students are hardly provided with the opportunities to experience the fun of learning Science, and nurturing their innate curiosity and other thinking abilities.

Discussion

Purpose of Science Education

Teachers' knowledge and belief about Science education and inquiry have been one of the leading areas of research since 1990s (Lederman, 1992; Cobern and Loving, 2002). Conceptual understanding of teachers into aims of Science education is a precursor to the effective and meaningful learning among students. Approaches that a teacher adopts in classroom are primarily determined by a deeper understanding of "what are the knowledge and abilities that can be developed among students through Science teaching?". It was found that almost 50 per cent teachers visualise Science purely as a body of knowledge. Although it was widely acknowledged that mugging up facts and concepts needs to be discouraged, it was not reflected in the classroom practices. Classrooms were encouraging memorisation of scientific concepts, principles and processes without deriving meaning out of it.

About one-third of them seemed to be cognizant of the significance of doing Science, but notion of Science teaching to develop thinking abilities, attitudes and values appeared to be feeble among Science teachers. A number of studies have shown concern over the unsatisfactory level of both teachers' and students' understanding of nature of Science (Duschl, 1990; Lederman, 1992). It is true that knowledge of scientific concepts and principles cannot be simply ignored. In many cases, they form the foundation of basis of high-order abilities. But it is crucial to incorporate such elements of teaching-learning to the classroom that engage students in activities fostering thinking abilities like scientists.

Very strong opinion emerged that scientific thinking can primarily be developed through systematic experiments in well-equipped laboratories. In contrast, absence of well-equipped laboratories cannot hinder learning scientific processes in school classrooms. For school students, each classroom has potential to engage students in scientist-like activities during which they can acquire Science process skills. Purpose of such tasks must be to ignite thinking, and to provide them triggers to construct questions that need investigation. Existence of näive ideas among teachers about aims of Science education indicates the need and scope of advancement in Science teacher education programme in the country, at pre-service as well as in-service level.

Teaching Learning Practices in Classroom

A teacher needs to use a variety of methods and tools in the classroom depending upon the topic, learning and age level of the learner and learning objectives. Availability of resources, socio-cultural factors and school leadership also have a significant influence on teaching methods. Classroom practices are one of the strongest indicators of teachers' understanding about "Aims of Science Education" as well as "how do students learn Science?".

Dominance of rote learning methods encourages the students to receive and reproduce the information without any processing, and thus restricting their creativity and problem-solving abilities. The scene does not seem to have changed over decades. Textbooks and blackboard are still common resources and material used by maximum teachers. Overdependence of Science teachers on textbooks is well documented (Stake and Easly, 1978; Weiss, 1993). In their study, Stake and Easly (1978) found that 90 per cent teachers use textbooks or other instruction materials 90–95 per cent times in their classrooms. Although teachers were aware that Continuous and Comprehensive Evaluation (CCE) demands variation in methods, but they found it difficult due to various reasons like higher number of students in a class, lack of understanding on how to do and many other infrastructure and administrative issues.

It was further found that 25 per cent teachers adopt teaching-learning methods that provide students opportunities to use their basic instinct to observe and explore (Table 2). Some projects were certainly assigned, but they were far away from the practices of project-based learning. Project works were usually restricted to predetermined presentations, models, charts, reports, etc. Most often these tasks are accomplished at home. In such circumstances, focus of the project revolves only around the end product and process aspect part remains ignored. They fail to engage students in thinking and/or working in a scientist-like manner.

Findings indicated very limited use of scientific methods and inquiry learning in the classrooms. Most crucial consequence of such practices is that students start visualising Science as a source of knowledge. There is ample evidence that students hardly get any opportunity of asking questions; formulating hypothesis; testing to validate them; and, communicating their findings. Learning Science requires students to engage in a scientist-like manner within and outside the classroom; and most involve observation, imagination, hypothesis and reasoning. There is a need to develop a culture promoting discovery of new knowledge that marks a significant shift from the existing trend to transfer established knowledge.

Status of Questioning and Scientific Inquiry in Classroom

Teaching is more meaningful and translates effectively into learning, when students are curious and alert. Observant and curious students pose a number of questions which most often governs the teaching learning process. Questioning is a reflection of curiosity that is an essential component of a live Science classroom. Howard Gardner has stated in his book, *The Disciplined Mind*– "*Habits of mind are important goals of education and can be nurtured through questioning and reflection*" (Gardner, 1999).

It has been discussed in previous sections that questioning in classrooms is analogous to testing and there is no room for student's curiosity in the entire learning process. Questions are rarely used as a trigger for teaching learning. Traditional education system with closed classrooms discourages the natural inquisitiveness to question and as students grow in age and grades, they pose less questions. The teaching practices promote listening and reproducing instead of observing, questioning and exploring. Reasons might be manifold, but it is very clear that students are getting minimal chances of knowledge construction, through scientific methods.

In the Report on *How Students Learn Science*, Magnusson and Palincsar highlight the significance of questioning as: "*Engaging children* *in Science, then, means engaging them in a whole new approach to questioning. Indeed, it means asking them to question. . . It means questioning the typical assurance we feel from evidence that confirms our prior beliefs, and asking in what ways the evidence is incomplete and may be countered by additional evidence."* (Magnusson and Palincsar, 2005)

When students are encouraged to construct their own knowledge and understand the relevance of Science in their coursework and life, their attitude towards Science improves (Novak, 1988). The National Knowledge Commission has expressed concerns over a talent crunch in Science, with the economic growth (NKC, 2009). There is an urgent need to reduce information-transfer and shift towards meaningful methods of learning Science.

Feasible Approaches to Address Some Key Issues

Integration of Curriculum, Teaching and Assessment

The Report to Nation (NKC, 2009) has recommended systemic change in Science pedagogy at all levels of school education, and has emphasised the need to revisit curriculum to make it more interesting and engaging for students. Curriculum, teaching-learning and assessment are considered as the three integral components of education, so a systematic approach integrating all components is desirable to achieve the required changes in the education system.

In standards based systems, these three components flow from standards that do possess the potential to guide and shape curriculum, teaching and assessment. Well-stated standards and learning expectations support teaching-learning and assessment by providing tasks that are measurable and observable. Standards and assessments examine the alignment between learning objectives and learning experiences; evaluate the appropriateness of teaching materials and the effectiveness of teaching strategies; measure what and how well students are learning in their classrooms; and directly match the students' learning with the attainment of curricular goals (Sharma, 2015).

Irrespective of class levels, standards should explicitly state what is it that "students should know, can do and think". Standards (or content standards) and performance expectations (or performance standards) need to be articulated with underlying principles that (a) students cannot properly understand scientific concepts without engaging in the scientific processes, and (b) they can demonstrate competence in scientific practices in the context of specific content. It is equally important to acknowledge and consider that cross-curricular and multi-disciplinary concepts provide students with cognitive and non-cognitive tools that can enhance their ability to understand and apply practices in specific content domains.

In the last decade there has been lots of work to extend standards and benchmark them against the research findings of cognitive Science– how students learn. This approach of learning system based on learning progression holds great promises to improve quality of Science learning among students.

Problem-based Approach of Learning

Use of Problem-based learning (PBL) in classrooms can be traced to mid-1960s as an alternative method to the conventional approach of teaching. The PBL method is well aligned with the constructivist approach of learning, because it allows students to relate their previous knowledge with their newly acquired knowledge, while working in groups to solve real life problems (Tarhan and Acar, 2007). PBL uses problems as a stimulus or learning tool for students, enable to construct their knowledge and improve their problem-solving skills. These problems simulate daily life complex problems rooted in situations that the learner is likely to encounter in the world outside of school (Woods, 1985). A group of learners is provided with a well-formulated problem and while discussing various aspects of the problem within their group they stimulate their prior knowledge. On the other hand, in the conventional teaching, problems are used to apply related concepts and principles at the end of a content unit.

Main features of the Problem-based learning method may be listed as:

- Learning is student-centred.
- Learning takes place in small groups, usually 6–10 students.
- Role of teacher is replaced by that of a facilitator.
- A problem is used to organise the group and trigger learning.
- PBL nurtures collaborative problem-solving skills and stimulates the cognitive processes.
- New knowledge is drawn from the pre-existing knowledge.

Boud and Feletti (1997) have specified few generic steps to implement PBL method in the classrooms. Processes of the PBL are similar in many aspects to the essential features of scholarly inquiry — its processes and objectives align with those of the research experience, making such learning opportunities accessible to a broader population of students. Students assess their knowledge themselves, identify their learning gaps, and obtain the required information through their own investigations.

Success of PBL method lies on the rigour in defining problems. End-of-chapter textbook problems in general do not require the analytical, synthetic and evaluative thinking needed for PBL, nor do they provide the contextual richness (Duch, 1996; White, 1996). On the other hand, ill-structured problems fail to provide all the information necessary to develop a solution, introducing uncertainty about the path towards resolution as well as about the goals (Qin *et al*., 1995). Basically, the major limitation of PBL is that it incorporates a formal learning cycle of activities that may take as much as several weeks to complete, depending on the nature of the problem (Boud and Feletti, 1997).

Inquiry-based Classroom

Inquiry Learning or Inquiry-based Learning (IBL) is the systematic investigation of questions to explore their answers and answers of such questions are either unknown or unclear. Inquiry method is basically simulated research, because both research and inquiry require the same kind of mental activities. However, they differ in the outcome of the activity and its relevance for the body of knowledge.

IBL is not a new concept. The method has its roots in John Dewey's book, *Democracy and Education* (1916) that describes how true learning begins with the curiosity of learners. The Theory of Inquiry (Dewey, 1938) advocates that inquiry teaching involves allowing children to learn from direct experience and cultivate their natural curiosity; and, the essentials of creative thinking lie in the processes of Science. Since then, Science educators have been advocating and promoting the methods of inquiry in Science classrooms (Schwab, 1962; Orlich 1989; Cherif, 1995; Wenning, 2005, 2007). It is obvious that 21st century Science education reform calls for pedagogical shift from a teacher-centred, textbook-based instructional paradigm to a student-centred, inquiry-based model (Kahveci, 2010).

One may argue that the purpose of Science teaching in schools is not discovery or invention, but one needs to be cognizant that the purpose of inquiry learning in school teaching is to help students to experience the scientific processes involved in the construction of scientific knowledge. Throughout the course of study, engagement of students in activities that promote and foster scientific inquiry emerged as a rare practice in the classrooms. Inquiry learning has proven to be a powerful tool in learning Science and also in influencing students' attitude and belief towards Science (Duschl, 1994). Reasons shared by the respondents varied from stringent norms to deliver a fixed content within given timeframe to a lack of awareness and how to do factor. But all these factors were hindering concretion of a collaborating learning atmosphere between teachers and students. Such classroom practices fail to develop and sustain interest among students for the subjects.

New millennium has witnessed a decline in students' enrolment in Science discipline in higher education (NCAER, 2005). *India Science Report* by NCAER (2005) expressed concern over increasing dissatisfaction of students with teaching of Science in the higher classes in school; and, stated that 45 per cent of the students did not pursue Science after Grade X due to lack of interest, and almost one third due to lack of motivation. This makes it imperative to engage students in construction of the knowledge in a meaningful manner.

Five essential components of inquiry learning that apply across all grade levels are: (i) engagement of students in scientifically oriented questions, (ii) priority to evidence, (iii) formulation of explanations from evidence to address these questions, (iv) evaluation of explanations in light of alternate explanations reflecting scientific understanding, and (v) communicate and justification of their proposed explanations (NRC, 1996). In simple words, the process of IBL consists of a researchable question, a methodology to explore an answer to the question, an answer to the question, a conclusion based on the answer, justification of the conclusion with the evidence and arguments, critical evaluation of the answer and the conclusion, and dissemination of all earlier points.

Question may arise about the age and grade level, when students can engage in investigations. Wenning (2005, 2007) has presented different levels and types of inquiry activities with varying degrees of teacher intervention and intellectual sophistication. As per Wenning's taxonomy, inquiry tasks might vary from teacher-guided to student-regulated pedagogy, depending upon the age and class level.

Irrespective of forms and levels of inquiry learning, the basic processes are common. According to Suchman (1966), the steps of the inquiry are to:

1. present discrepant events or specific problematic situation;
2. encourage observations of developing a statement of research objectives;
3. ask students for observations and explanations (testable hypotheses);
4. encourage the testing of those hypotheses;
5. develop tentative conclusions and generalisations; and
6. debrief the process.

National Science Teachers Association of the US identifies scientific processes like observing, questioning, hypothesising, predicting, investigating, interpreting, and communicating as steps of inquiry (NSTA, 2003).

Mohanan and Mohanan (2012) identify asking questions, looking, noticing, and thinking, as four central activities of scientific inquiry and elaborate:

"…. *Given that inquiry is the investigation of questions, it follows that all inquiry begins with questions... The capacity to discover and formulate interesting and significant questions that call for investigation is the very first step in inquiry. The capacity for* *looking and the capacity for noticing is a fundamental quality for scientific inquiry… Thinking is a cluster of mental activities directed towards a goal. Designing an experiment to test the hypothesis that obesity is contagious requires thinking, and if it is contagious, inventing a theory that explains how it spreads also requires thinking".* (Mohanan and Mohanan, 2012, pp. 3–4)

These steps might not be necessarily linear and distinct, but these skills play a critical role in helping children develop scientific ideas and concepts.

Professional Development and Capacity Building of Teachers

Teachers' awareness of nature of Science, aims of Science education and innovative practices like inquiry are must to implement best practices of Science teaching-learning in the classroom. It supports them design a conceptual framework of scientific inquiry, and create a collaborative and enriched learning environment, so that learners can construct their knowledge with new questions, hypothesis and investigations in a democratic manner. The framework developed by teacher and the enabling environment would support students to accomplish their learning objectives. Teacher is required to maintain a delicate balance between the guidance and child's creativity and thinking; and, between scientific concepts and processes.

Lederman (1999) advocates pursuing and evaluating systematic and concerted efforts to help teachers develop their conceptions, skills and abilities in order to enable them to transform their Science knowledge in classroom practices. Wenning's (2007) framework for the assessment of scientific inquiry that might guide teachers to formulate strategies for inquiry learning in their classrooms success of Inquiry learning depends exclusively on the learning environments and the role of teacher.

Effective Implementation of ICT Supported Learning

Tools of ICTs can make Science teaching-learning more versatile and goal-oriented. Besides this, they motivate students and promote creativity and interpersonal skills like cooperation and collaboration. ICTs, for example, offer a range of useful tools for use in school Science activity, like tools for data capture, processing and interpretation, data logging systems, graphing tools and modeling environments. Different forms of ICT can enhance both the practical and theoretical aspects of Science teaching and learning. Osborne and Hennessy (2003) have identified potential contribution of ICTs in classroom teaching as:

- expediting and enhancing work production; offering release from labour intensive manual processes and more time for thinking, discussion and interpretation;
- linking school Science to contemporary Science and

providing access to experiences not otherwise feasible;
- supporting exploration and experimentation by providing immediate, visual feedback;
- focusing attention on over-arching issues, increasing salience of underlying abstract concepts;
- fostering self-regulated and collaborative learning;
- improving motivation and engagement.

(Adapted from Osborne and Hennessy, 2003)

However, it is not appropriate to assume simply that the introduction of such technologies necessarily transforms Science education. Rather, we need to acknowledge the critical role of teacher, in creating the conditions for ICT-supported learning through selecting and evaluating appropriate technological resources, and designing, structuring and sequencing a set of learning activities. As the school curriculum goes beyond classrooms and establishes links with the external scientific and social communities, ICT has to play a central role in supporting development of scientific reasoning and critical analysis skills. It can help teachers both in facilitating key aspects of scientific thinking and in bridging gap between schools and social and scientific communities.

Conclusion

In the era of knowledge and information based economy, most of the developments are expected from Science and technology. There is a continuous demand for improving quality of Science education. The study enforces that Science teaching in classrooms does not encourage young minds to question, to formulate hypotheses, to look for alternative solutions and develop an attitude impregnated in values of humanism. On the other hand, development of high order thinking skills like logical reasoning, critical thinking as well as on fostering scientific attitude, values, interests and humanism have always been the integral components of Science education.

Bridging the gap demands a major shift in perception — from knowledge to spirit and abilities of inquiry; and, from a prescribed list of contents to the "spark of excitement" that stems from discovery. There is a need to begin with well-defined standards and clear understanding of learning objectives not only in terms of conceptual knowledge, but also in terms of skills, attitudes, values and overall mindset. Classroom practices should be oriented towards the achievement of these learning objectives. With the help of relevant tasks, students need to understand the world around them and make rational decisions.

Teachers' ability and professional development is vital for students' learning. Out of a variety of methods, teachers must decide a method that is most suitable and productive for accomplishing learning objectives. Classroom practices that aim to influence students' attitude and belief towards Science and foster a spirit of scientific inquiry, would enable realising the goals of Science education.

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