Analysing Middle Grades[1] Science Textbooks for their Potential to Promote Scientific Inquiry

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Abstract

Textbooks constitute the toolkit (Chinn et. al., 2002) used by teachers to foster scientific temper among their students. By this token, this study seeks to examine the middle school science textbooks of two publications, NCERT and Eklavya, for the ways in which they support scientific inquiry. The 5E model of inquiry based science learning is used to analyse textbook activities for their ability to support inquiry. A proposed plan in terms of centrally placing inquiry based tasks in curriculum organisation, furthering student engagement, and facilitative role of teachers is presented. It is hoped that contextualising science by the means of inquiry based textbooks would strengthen the bonds between science and society and develop critically inquiring minds contributing to the progress of scientific pursuit throughout their lives.

Introduction

"If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be INQUIRY." (DeBoer, 1991, p. 206). While understanding the available discourse in science education, it becomes evident that science education has received an exceptional attention from both education and political stakeholders. Many efforts have been made to improve science teaching and learning in non-customary ways. In USA, science education reform initiatives have targeted on scientific literacy through inquiry experiences and skills "for all" (AAAS, 1990, 1993; NRC, 1996).

This attention on promoting inquiry seems to reflect a belief that inquiry approach to teaching and

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learning probably reflects quality science education. While unpacking what does inquiry based science education (IBSE) entails, it comes forth that it has been characterised in a variety of ways over the years (Collins, 1986; DeBoer, 1991; Rakow, 1986 as cited by Haury, 1993). Some have emphasised on the active nature of student involvement, associating inquiry with "hands-on" learning and experiential or activity-based instruction. Others have linked inquiry with a discovery approach or with development of scientific process skills. (Novak, 1964) suggested "Inquiry is the [set] of behaviours involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious." So, inquiry involves activity and skills, but the focus is on the active search for knowledge or understanding to satisfy a curiosity (Haury, 1993).

Moving ahead with this as operational definition of inquiry in science, it is worth noting that few commentators of IBSE have contrasted inquiry and textbook-based approaches to teaching – learning of science. A textbook-based approach is often interpreted as teaching by largely depending on and following textbook content, which is interpreted as distinct from inquiry approach. Settlage (2007) highlights that inquiry "has long been promoted as the antidote for teaching science directly from a textbook" (p. 464) and Von Secker (2002) indicates that science education reform calls for pedagogical shift from a teacher-centred,textbook-based instructional paradigm to a student centred, inquiry-based model (Kahveci, 2010).

Although these distinctions have often been made on an "either/or" basis, textbooks are still being widely used in classrooms and continue to be an essential part of the curriculum. Various scholars indicate that science textbooks have played a dominant role in the teaching of science and have been mostly 'seen' as the science curriculum by stakeholders (Chiappetta and Fillman, 2007; Pizzini, Shepardson and Abell, 1992 cited by Kahveci, 2010). Harlen (1998) pointed out that there are three ways in which teachers use textbooks. The first group centres their entire pedagogical processes around textbook, the second uses it as a resource coupled with other tools and the third group of teachers avoids using it. Whatever the extent of usage, but textbook is an important feature of science teaching-learning in schools. However, despite repeated efforts and recommendations by several researches and policy documents it has been a common observation that schooling often promotes textbook dominance. Specifically, in Indian culture, importance of textbook is often traced back to British Raj period where the agenda was to create a service class in Indian society to serve the colonial needs who could regurgitate facts and procedures under certain pre-designed situations. These agendas gradually became ingrained in our school system leading to creation of 'textbook culture' in which the entire schooling came to be structured around textbooks (Kumar, 1986). (Sarangpani 2003) in the same line suggested that in Indian schools, textbooks not only control products but processes of teaching-learning. Providing an international perspective to the issue, Chiappetta and (Fillman 2007) stated that science textbooks are used as the primary organiser of subject matter at all levels of schooling (Kahveci, 2010).

Drawing on these assertions the prominent position of textbooks for effective and all-inclusive teaching and learning becomes evident.

Science Textbook Analysis

Research echoes the fact that most of the science textbooks are teacher directed. Experiences for exploration, if and only if they exist, are textbook or teacher directed (Vijaysimha, 2013). Pedagogical tools evoked through such textbooks mainly involve listening and reading, students are often found engrossed in notes taking, and assessment is based on short, atomised aspects of the curriculum. All the more, inquiry is interpreted as restricted to science laboratories where structured and specified opportunities to exploration are prescribed. This view disconnects inquiry from science lessons occurring in regular classrooms.

Eventually, while reflecting upon science teaching and learning in Indian classrooms, it seems that the role of textbooks and the ways in which teaching-learning processes are conducted is worth investigation.

An extensive textbook analysis procedure has been developed within the frame of the AAAS Project 2061, based on seven main categories (AAAS, 2005). Other past and also up-to-date evaluations of science textbooks involve various analyses from certain perspectives, such as representations of gender and sexuality (Snyder and Broadway, 2004), gender equity (Elgar, 2004), questioning level (Pizzini et al., 1992), science vocabulary load (Groves, 1995), content accuracy (Hubisz, 2003), or the inclusion of the nature of science aspects in biology (Chiappetta and Fillman, 2007; Irez, 2009) and chemistry (Abd-El-Khalick, Waters, and Le, 2008; Niaz, 2005) textbooks (Kahveci, 2010).

Furthermore, research literature on science textbook analysis indicates that the subject matter should be divided into themes for content analysis. Different researchers have been using different themes for the purpose, such as Wilkinson (1999) used the themes related to scientific literacy, Vesterinen et al. (2011) had themes related to nature of science, and Dimopoulous et al. (2003) related them to visual images, and Schussler et al. (2010) explored the specific knowledge provided by the textbooks by looking at the headings of various topics and content that is included in each of them (Dunne et al., 2013). In the present context, the themes of 5E model would be used and content would be analysed in relation to it.

The Textbooks

For the purpose of textbook analysis, two publications or series of textbooks for same grades are chosen. These publications are one from NCERT, and the other produced through the renowned science popularisation project, Hoshangabad Science Teaching Programme (HSTP), started in 1972 in the Hoshangabad District of Madhya Pradesh in India for over 20 years. It had resulted in the development of textbooks named '*Bal Vaigyanik*' series for middle school science. The major thrust of this programme was 'learning by doing' and the basic tenet of their textbooks is 'Before children can understand a thing, they need experience - seeing, touching, hearing, tasting, smelling, choosing, arranging, putting things together and taking things apart. Children need to experiment with real things' (Gupta, 2010). Moreover, the scientific equipment used for performing experiments was low cost as against the populist view that science experimentation requires high end and expensive apparatuses. This publication has gained extreme repute amongst academics in India. And hence it seemed important to analyse these textbooks for the extent they contain the features and characteristics of pedagogy of inquiry based science education.

The second series of books chosen are published by National Council of Educational Research and Training (NCERT). This is a central body whose one of the key responsibilities is the development of textbooks in accordance with recent advancements in the educational discourse. These books are undoubtedly considered to be the state-of-the-art and sacrosanctly adhered in most of the Indian schools. With the advocacy of NCF (2005), these books have been revised to place scientific inquiry at the centre stage and contribute towards inquiry based science education. Therefore, it is important to analyse what are the characteristic features of these books as they are widely used by majority of school going population in India. For feasibility purposes, seventh grade textbooks of both the publications are examined.

Though the intention is not to steer a competition between the two publications but to arrive at an informed understanding of what is inquiry based science education, what are its prominent characteristics and how can it be included in textbooks to achieve the best of outcomes?

Rationale and Purposes of the Study

This study attempts to explore the ways in which science textbooks can be structured to promote inquiry.

Following research questions in particular guided the study:

- Ability of activities presented in them to involve students in 5E model : Engage, Explore, Explain, Elaborate, Evaluate (Dunne et al., 2013).
- Ways in which sequencing of science instruction and inquiry has occurred: Does text organisation make exploration compulsory or activities simply hinge onto the central text?
- Level and nature of student involvement present.

And in order to arrive at solutions, textbook analysis seemed to be most appropriate methodological tool.

Research Methodology

The methodology used in this study is based on a content analysis of the textbooks. An in-depth probe into the ways in which text is organized, nature of activities chosen and the ways in which they are presented, sequencing of text material, titles of the chapters and the nature of scientific content included, etc. is made. For the purpose of analysis, 5E model of inquiry is chosen as the analytical framework as it gives scope for a strict, objective analysis of themes as well as content of the textbooks.

The 5E instructional model was developed for the elementary school science program *Science for Life and Living* by the Biological Sciences Curriculum Study Organisation (BSCSO, 1990). This approach to teaching science through inquiry is recommended by BSCSO in their curriculum framework for teaching about the history and nature of science and technology. As the name implies, the 5E model has five phases: Engagement, Exploration, Explanation, Elaboration and Evaluation which are described as follows:

Table 1
The 5E model of inquiry

Engagement	Strategies and activities designed to elicit thoughts or actions by the student that relate directly to the lesson's objective
Exploration	Experiences where students' current understandings are challenged by activities, discussions and currently held concepts to explain experiences
Explanation	Presentation of scientific concepts that change students' explanations to align with scientific explanations
Elaboration	Activities that require the use of applications and use of scientific concepts and vocabulary in new situations
Evaluation	Culminating activity that provides the students and teachers with an opportunity to assess scientific understanding and intellectual abilities

Source: Dunne et al. (2013, p. 1519)

This framework is vast enough to allow for almost all the activities to be placed under one of the headings. Two assumptions were made to allow for flexibility - first assumption involved Elaboration phase where it is expected that scientific concepts are applied to new situations but it is not often the case as the situations for applying the information were not always new and outside classroom; the second assumption was that assessment of student should go hand-in-hand through all the phases of 5E without the need of a specific activity all the time to assess pupils' understanding.

The next stage involved the development of a tool that would enable the placement of various ideas and activities in the textbooks under different phases of the 5E model. A tool was designed in such a way that it allowed for easy comparison of topics, books and the ways in which same content was conceptualised in both the publications. Each topic was classified under the 5E categories and qualitative description was also added to allow for easy and comprehensive comparison between various activities that the textbooks promote.

Table 2 provides an illustration of how the tool is used to classify various textbook materials under different sub-headings of the 5E model. Another added dimension of the analysis is the order element being carefully investigated through the tool, i.e, sequencing or the order in which material is organised under various sub-headings in the textbook to understand does sequencing of the text material play a role in enhancing inquiry or alternatively stated what would be the best way to organise material to enhance inquiry approach of the lesson.

Table 2

Topic	*Engagement*	*Exploration*	*Explanation*	*Elaboration*	*Evaluation*
Light	Arrange three empty match boxes with a hole in each of them to make the light from a candle visible across all of the match boxes	What does this experiment tell you about the path of light? What happens to the image if the screen is moved forward or backward?		Make your own pinhole camera (process explained)	Why can't you see your friend who is sitting in the next classroom of your school?

Analysis

Activities form the essence of Inquiry Based Science Education (IBSE) and to unpack how they truly initiate inquiry is fundamental to this study. In this part of data analysis, activities that form the individual phases of the 5E are described. Activities or experiments from both the textbooks are placed under one of the categories (however, there existed the scope of overlap among categories which is acknowledged). And frequency of activities being included under one of the categories is noted. It is followed by a qualitative analysis of the quality of experiments included in the textbooks which is determined against the conceptual framework so developed on scientific inquiry.

As previously discussed, **Engagement** activities are designed to elicit previous knowledge, thoughts and actions of the students related to the lesson objectives. This phase generally constituted the introductory session of the science lessons to create a base for further knowledge construction. It was found that both the series laid emphasis on this aspect of inquiry but their approaches differed. Textbooks of NCERT publications often encouraged students to indulge in small activities which were very simple. Moreover, the scientific explanation is often provided as soon as the explanation of the activity ended which often proved to be a hindrance to the real time pupil engagement in the activity. For instance, in the chapter Electric Current and its Effects, an activity on construction of electromagnets is described.

Box 1

Take around 75 cm of a long piece of insulated (plastic or cloth covered or enameled) flexible wire and an iron nail, say about 6-10 cm long. Wind the wire tightly around the nail of a coil. Connect the free ends of the wire of the terminals of the cell as shown in the figure.
Place some pins on or near the end of the nail. Now switch on the current. What happens? Do the pins cling on to the tip of the nail? Switch off the current. Are the pins still clinging to the end of the nail? (NCERT, 2009, Class-VII, p. 168).

This engagement activity is immediately followed with an explanation of the possible observations that should have been made[2] and the scientific reasons behind it - “The coil in the above activity behaves like a magnet when electric current flows through it. When the electric current is switched off, the coil generally loses its magnetism. Such coils are called electromagnets”. (NCERT, 2009, Class-VII, p. 168).

The nature of activities primarily included a range of cartoon initiated queries “Boojho and Paheli”, Panchtantra stories, etc., relating science to real life situations but often lacked rigorous scientific investigations. Manipulation with a limited range of material was seen and the focus was more on observation. While the Engagement phase in *Bal Vaigyanik* included multitude of activities to involve students in the scientific pursuit. For instance, they used narratives, discussions, design and model making (make your own kaleidoscope), reading, observing, planning investigations (make your own cell using lemon juice, tamarind juice, tomato juice instead of sulphuric acid), manipulating lots of concrete material (which is readily available), description of historical aspects of scientific development (how cell was discovered by Volta). In all the cases, scientific knowledge was the by-product of pupil engagement with the scientific pursuit.

The **Exploration** phase, as delineated in the table, is where students' current understanding is challenged by activities, discussions to explain experiences which are often provided by the Engage phase. This phase was sparsely dealt in NCERT publications as only a few situations were provided (for instance, observe your face in a spoon, front and back, etc.) that may challenge pupils' current states of understanding. All the more, the activities present were found to be primarily catering to the observation process skill without giving due guidance in ways of recording these observations. Whereas, in *Bal Vaigyanik,* guided experiments were the prime focus in which students were provided with the process to follow. They were rigorous in the sense that they employed lots of process skills, question raising, manipulating concrete material, observing, inferring, etc. To illustrate, the textbook provided students with directions to themselves elucidate laws of reflection and manipulate the set to record various cases. Rather than supplying scientifically validated information, it was constructed through learners. All the more, the entire lesson invoked exploratory activities which were evenly scattered throughout the text. Therefore, inquiry was not a one-shot process restricted to the lesson introduction or at the end as an assessment task but was a compulsory feature of science knowledge building.

The **Explanation** phase included presentation of scientific facts and concepts to align students' understanding with scientifically validated knowledge. It was found that NCERT had prime focus on 'telling' students what they must have observed. Almost all the activities in first two phases culminated with scientific facts explained by the author. An example is given below.

Box 2

Activity: Take a stainless steel spoon. Bring the outer side of the spoon near your face and look into it. Do you see your image in it (Fig. 15.10)? Is this image different from what you see in a plane mirror? Is

> this image erect? Is the size of the image same, smaller or larger?
> Now look at your image using the inner side of the spoon. This time you may find that your image is erect and larger in size. If you increase the distance of the spoon from your face, you may see your image inverted. You can also compare the image of your pen or pencil instead of your face (NCERT, 2009, Class-VII, p.179).

As evident, that what a student would have observed is pre-stated which restricts pupils' involvement in the process. In such cases, children often hesitate to raise questions, describe their alternative views and other observations which are not directly related to the content.

In addition, the sub-topics were too prescriptive to suggest what scientific concept to explore while doing an activity. For instance, one of the titles of a topic in chapter 'Light' was 'light travels in a straight line'. Such titles supply students with readymade knowledge hence barring the process of scientific inquiry. Contrastingly, in *Bal Vaigyanik* it was found that instead of providing students with information it provided them with activities to construct the relevant knowledge, identify errors or misconceptions that must be addressed before proceeding on to the next activity. While referring to the same concept, this book had title *The Path of Light* which is relatively open. Such titles do not dictate scientific information but provide for avenues to explore what could be the science behind their observations. However, this approach does not negate explanation but enables the learners to create it for themselves instead of engulfing packed pieces of information.

The **Elaboration** phase is concerned with activities that require the application and use of scientific facts in new situations. *Bal Vaigyanik* had several such activities interspersed throughout the lessons. One example of this application of knowledge is described as the students designing of a kaleidoscope, pinhole camera, etc. Apart from these, several other tasks were included to relate the scientific knowledge at home and hence embed science in their everyday lives. For instance, household measures of volume like feeding bottles, glucose bottles, medicine bottles, mugs, buckets, etc. were introduced as measuring instruments and students were encouraged to find out their least count (Class VII, p. 87).

NCERT also utilised different tasks for elaboration but sparsely. Some of the examples were prominent in the section 'Extended Learning-Activities and Projects' that featured at the end of the lesson after the exercise questions were presented. Its positioning often relegated it a status of being 'optional' or 'extra' and thus there is a possibility of it being overlooked. However, scope for inquiry is there with activities such as make your own rainbow, visit a laughing gallery, dentist, etc., role playing which if compulsorily followed could enrich the curricular and pedagogical processes.

The final phase is **Evaluation** and as had already been described it does not only cater to formal modes of assessment but refers to formative, classroom based modes of assessment that assesses pupils' understanding on regular basis. It may include activities, such as, creating posters, answering questions, discussing investigations, etc. It was found that NCERT often focused upon recall based short questions, such as, 'What is a virtual image?' State one situation where a virtual image is formed, List the differences between clayey soil and sandy soil, etc. All the more, questions were organised in terms of fill in the blanks, match the following, multiple choice questions, etc. which culminated the inquiry into rote memorisation as 'what is assessed often becomes what is taught' (Cheng, 2000). On the other hand, in *Bal Vaigyanik*, assessment was happening unobtrusively throughout the lesson. All the activities promoted students to perform and record their observations followed by drawing of inferences. In this process, what knowledge is created by learners becomes evident, learning gaps can be identified, and hence adaptive measures can be taken then and there. To focus upon end of the chapter questions, it came forth that multiple modes of eliciting assessment evidence were employed, to illustrate, the assessment task on Motion chapter was 'To plot a graph of the famous story of race between a hare and a tortoise.' which will motivate learners to creatively plot a story and apply scientific knowledge to real life situations; the structured questions given as back exercise in the Electric Circuits and Cells - 'you have seen and used many electric appliances. List them. Each has some information written on it - for example, its voltage, wattage, etc.... Consult your teacher to find out their meaning, and what they tell you about the appliance' — this question was not text based and created a preparatory base for concepts to be included in the next grade.

Upon examining all the activities of the textbooks, it came forth that though both the books are student-centric but *Bal Vaigyanik* employs lots of diverse range of activities for students to construct scientific knowledge instead of supplying the information. This is in alignment with several policy documents, such as, position paper on Teaching of Science (2006), NCERT Source Book on Assessment, and international trends of Inquiry Based Science Education (IBSE). This approach towards content organisation displays a constructivist approach rather than a deductive approach to teaching-learning of science. Furthermore, contextualisation of science emerged as an added feature for the promotion of inquiry, specifically in *Bal Vaigyanik*, and hence would be helpful in translating scientific temper to real life situations.

Concluding Thoughts

Textbooks form one of the crucial guiding lamps for school education. Its organisation, nature of content included, types of pedagogical approaches described often becomes 'what is science' to most teachers and students. Inquiry based learning requires development of instruction by the means of activities in which student engagement plays the crucial role. Activities need to be truly exploratory in nature that is involving students in discovering, planning, monitoring and proposing answers.

The differences between the textbooks, however, may seem trivial but in collectivity they have a huge impact on the way teachers derive their conceptual, pedagogical and assessment implications from the textbooks. The results of this study suggest several nuances among science textbooks used in middle grades in India from which several conclusions can be drawn–

Physical Aspects: NCERT textbooks have made considerable efforts to make science learning interesting to learners by integrating colourful pictures, cartoon characters such as Boojho-Paheli, using pleasant visual imagery to make the text look interesting to young learners. Also, they have suggested various field visits to further relate the concept to learners' daily lives which can be taken up later as an extended project. On the other hand, Eklavya publications had lots of interesting activities but their packaging was in black and white which may not appeal immediately to young learners.

Differing Orientation of Curriculum Designers: It came forth that under same themes the textbooks were covering different topics, suggesting the distinct vision of curriculum designers about the cognitive validity of scientific content. For instance, in the theme of 'Electricity' in Class VII, NCERT textbook included the concepts of magnetic and heating effects of electric current while *Bal Vaigyanik* included the concepts of series and parallel circuit.[3] Both publishers included different scientific content in their books.

Additionally, complexity of activities chosen for promoting inquiry considerably varied. That is to say, Eklavya promoted rigorous experimental procedures while NCERT preferred simple tasks involving only a few science process skills.

Content vs. Process Orientation

While analysing NCERT, it came forth that pre-occupation with scientific principles often lead to content-orientated textbooks and teachers may skip the inquiry-oriented activities to arrive at packets of information. It can be called that NCERT publication is content-oriented and can be used as a resource for IBSE (Inquiry Based Science Education) if the teacher adequately builds upon the lesson structure by incorporating other elements of 5E inquiry model.

On the other hand, *Bal Vaigyanik* (Eklavya Publication) series contained all the processes and structures of the 5E framework. It provided teachers with diverse pedagogic tools, hence, it can be described as promoting both conceptual understanding and scientific process skills among learners. Moreover, Eklavya Publication books attempted to contextualise science to a great extent. The characteristic feature of this publication is that every theme is introduced by making children reflect upon his day-to-day observations. He is forced to take cognisance of his surroundings, ponder over the intricacies of various phenomena and think whether science can probably explain the reasons behind the seemingly obvious natural and physical phenomena. To illustrate, questions like 'Why can we not see in the dark?, How do our eye see things?' and so on are either followed by an explanation phase or an engagement phase in which pupils have to engage in an activity to find answers. This approach provides learners with an intrinsic motivation to engage with the discipline, hence, making science an internalised process.

In addition, inquiry was not restricted to specific themes but a few chapters were introduced just to initiate a joy of engagement with science, such as, 'Fun and Games', 'Games with Air' and 'Fun with Science' (Make your own rainbow) activities interspersed with themes. These fun-based activities which were optional in terms of content coverage welcomed the learners to experience science and mess around with things to develop familiarity with the ways in which natural and physical world works.

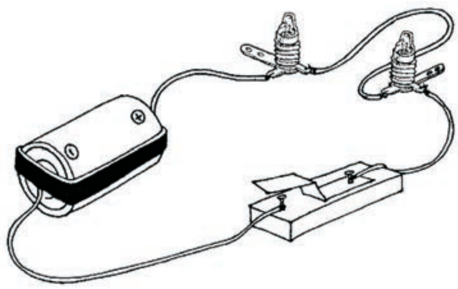
Sequencing of Activities

It is crucial to note that the way content is organised in the textbooks often structures the ways in which linkages are made between different themes and grade levels.

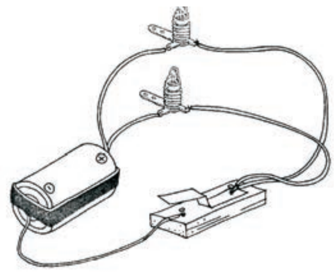
In Eklavya Publication, it was found that continuous reference to the topics placed under different themes was made. Also, any topic, such as, Electricity was spirally connected from Classes VI to VIII. This promoted holistic development of the scientific content. Also, there is smooth transition from one 5E sequence to another with the first building onto the other and leading to a coherent organisation of the text. For instance, as could be seen in the textbook excerpt, parallel circuits were built from the series circuit drawn in previous experiment. There are smooth transitions between different 5E phases as one stage built upon another.

Box 3

Make this circuit by joining two bulbs and cell-*Engagement*

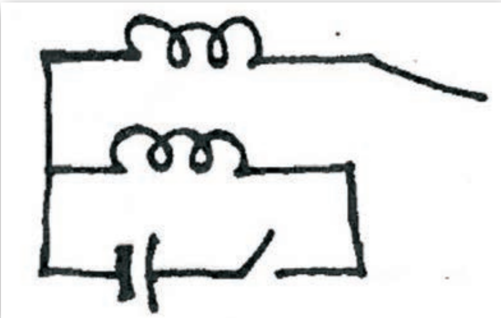


Do both the bulbs light up? Do both glow equally brightly?- *Engagement*
If one glows less brightly, will it shine more brightly if we change its place in the sequence? Take a guess. Now change the position of the bulbs to check whether the guess was correct or not.- *Exploration*
It is followed by *Explanation* phase- Sometimes, similar looking bulbs differ from each other and do not always glow equally brightly…
(This excerpt is followed by another experiment without providing any bold fonts suggesting a continuity between sub-themes).
Can you break the circuit in such a way that one bulb continues to glow while the other does not?- *Engagement*
How is the current affected when the current is broken at any place?- *Exploration*
How many paths are there in this circuit for the current to flow?- *Exploration*
This statement is followed by an explanation phase during which scientific terminology was introduced: 'You have made and observed a series connection. Let us explore another type of connection.' After this new title 'Parallel Circuit' was introduced which entailed:-
The bulbs in this circuit (referring to a circuit diagram of one cell and two bulbs connected in parallel) are said to be connected in parallel- *Explanation*
Take the bulbs you used to make the series connection and



connect them in parallel circuit- (*Elaboration* which was followed by a series of questions again initiating 5E inquiry) (Bal Vaigyanik, Class VII, P. 146-7).

Furthermore, the book represents a chain of experiments and hands-on activities giving explanation, per se, presentation of facts, a minimal space. The explanation phase is constituted of specific 'guess' based tasks where in students were motivated to make informed guesses from the concrete situations. For instance, What would happen if the connection of Bulb B is broken at one end? Take a guess and then test to see whether your guess was correct (p.147).



Furthermore, the book is organised around process skills and content is evolved through acquisition of process skills.

Nature of Assessment: Poor assessment tasks (Stern and Ahlgren, 2002) seem to cripple the process of inquiry as low order questions seeking information often promote teachers teaching to the test. Such tests (referred to high stakes formal ways of pupil assessment) often lay emphasis on rote-based teaching-learning which results in bypassing the path of inquiry to reach directly at the school science view. However, integration of open-ended divergent questioning interspersed throughout the lesson makes inquiry a compulsory feature to arrive at solutions.

Bal Vaigyanik did not provide answers, in terms of scientific facts, to all the assessment questions but described the ways to explore the possible solutions to the problems within the main body of the text. Self evaluation happens by default in this textbook as in order to arrive at the scientific principles, the child has to experience it, deduce inferences from it and explain it in a fashion that makes his knowledge scientifically valid. It also develops in him joy of creation, inquisitiveness, metacognition and other science process skills. Further, route of discovery of scientific knowledge becomes internalised which can then be translated to other new problem-solving contexts, thus, laying due emphasis on 'Elaboration' phase of 5E framework. Also, almost all tasks required pupils working in groups thus encouraging peer teaching, learning and assessment.

Teachers' Pedagogical Content Knowledge (PCK): It has been cited in literature that blind reliance on textbooks is attributed to lack of teachers' PCK (Dunne et al., 2013). In order to arrive at reforms in science education, it seems imperative that adequate PCK is provided so that teachers know how to use inquiry oriented textbook in its true spirit. It seems that teachers and textbook constructors themselves need to have a vast repertoire of inquiry oriented skills, due experience in science inquiry so that they can create activities suited to the age level, cognitive level of children while maintaining interest, innovation and scientific rigour. It may happen that in the absence of appropriate PCK, teachers revert to didactic teaching methodologies by bypassing the innovative pedagogical tools as realising the potential of inquiry oriented textbook requires an 'amalgamation' of teachers' pedagogic knowledge, content knowledge and knowledge of the classroom context.

Developing Student Ownership towards their Science Learning: A teacher involved in IBSE needs to share the classroom powers with learners. In fact, making pupils accountable for their own learning makes pupils responsible and reflective. It could only be achieved by 'engineering' (Black and Wiliam, 2012) learning tasks that stress upon active engagement of pupils in the meaning making process. One of the key elements is to clarify the learning intentions of the task, make the process transparent and suggest the movement towards learning progression of the concept involved. It was found that in Eklavya Publication, reasons for carrying out an investigation, experiment or activity are explicitly stated in terms of what questions will be answered after performing this activity. For instance, in the chapter 'Water-Hard and Soft', series of questions were delineated before describing an activity which could probably answer those questions.

Box 4

Which salts, when dissolved in water, make the water hard?
Are there any salts which, when dissolved in water, do not affect the softness of water?
Which salts when dissolved in water, leave a precipitate on adding soap?
Do you see any relationship between salts that form a precipitate and salts that make water hard? If you do, explain what this relationship is.
If you cannot answer these questions, do the following experiment (it was followed by the procedure of an experiment). (Bal Vaigyanik, VII, p. 42).

These questions adequately mentioned the learning objectives of the experiment to be followed performed. This often leads to students acting as scientists engaged in problem-solving situations akin to real life situations.

A Way Forward

A way forward in terms of curriculum organisation and the role of teacher in inquiry based learning can be drawn from this study. Inquiry oriented textbooks may prove to be a powerful resource in encouraging teachers and students to take recourse to IBSE. With appropriate developments in teachers' PCK, it could be hoped that pupils not only gain an in-depth scientific conceptual understanding but also get equipped with scientific process skills. These pupils would then contribute progressively to the process of knowledge construction and provide creative solutions to real world problems. Therefore, it seems important to encourage scientific inquiry in our classrooms in order to further relate science to society. It is because only by means of these reforms in science education it would be able to serve its purpose of dissemination and communication of scientific values to the larger world outside classrooms.

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[1] Grades being referred to are VI, VII, VIII

[2] However, research in science education notes that students observe different aspects even from a same demonstration made by the teacher depending upon their own interpretive frameworks (Driver et al., 1999).

[3] Whereas, the concept of series and parallel electric circuits in introduced at secondary levels in NCERT publications.

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