Effects of inquiry-based learning methods on Primary School Students' academic improvement

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Certificate of Examination

This is to certify that the dissertation titled **Effects of inquiry-based learning methods on Primary School Students' academic improvement** Submitted by Mr. Mohammad Irteza Rizvi (Reg. No. MS14052) for the partial fulfillment of BS MS dual degree programme of the Institute, has been examined by the thesis committee duly appointed by the Institute. The committee finds the work done by the candidate satisfactory and recommends that the report be accepted.

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Declaration

The work presented in this dissertation has been carried out by Irteza Rizvi with Dr. Anu Sabhlok and Professor Arvind at the Indian Institute of Science Education and Research Mohali. This work has not been submitted in part or in full for a degree, a diploma or a fellowship to any other university or institute. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due acknowledgment of collaborative research and discussions. This thesis is a bonafide record of original work done by me and all sources listed within have been detailed in the bibliography.

Irteza Rizvi (Candidate)
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In our capacity as the supervisors of the candidate's project work, We certify that the above statements by the candidate are accurate to the best of our knowledge.

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Dedicated to My Parents, Brother, Sister, Teachers and my close friends
For love, support, and encouragement

Preface

The initial motivation for this study came from my long-standing interest in the field of science pedagogy and learning methods. As the world progresses so does the teaching and learning methods. Which models are best suited for teaching science is an important question for developing countries like India where much time, effort and money has not been invested in exploring teaching techniques like foreign countries which might be justifiable for many number of reasons. This dissertation is divided into three chapters. The first chapter introduces the premise of science teaching and learning through history, the different learning theories and discussion on a constructivist theory of learning, i.e. INQUIRY-BASED SCIENCE EDUCATION(IBSE). The second chapter sheds light on the conditions and phases, science education in India has passed through and discusses some studies done in India regarding the efforts put into implementing the IBSE methods in classroom teaching. The third chapter enshrines the aims, objectives, methods and other details of the study undertaken with a conclusive discussion on the results of the study and prospects to be explored.

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I would first like to express my deep gratitude to my thesis advisors, Dr. Anu Sabhlok and Dr. Arvind. They have been extremely helpful and cooperative throughout the year. I thank them for allowing this thesis to be my own work and steering me in the right the direction whenever required.

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Abstract

This study deals with investigating the effects of inquiry-based learning methods on the performance of government primary school students. The study first delves into the evolution of the inquiry-based learning (IBL) philosophy and comparing the various studies that have been done either supporting or criticizing the IBL model. The study then delves deeper into questioning the position of science education in India by comparing different kinds of literature and attitude of teachers and students towards science education. To test the efficacy of IBL model (5E instructional model) over RTM(Regular teaching method) a government school in Manauli, Punjab is chosen, and the control group and experimental group are subjected to the two different pedagogical approaches. Then the performance improvement is tested through t-test to see if any significant improvement emerged from any of the approaches employed.

Chapter 1

1.1 Introduction

Many studies conducted on middle and high school students have concluded that inquiry-based science activities have positive effects on students' achievement in science in terms of cognitive development, laboratory skills, science process skills, and understanding of scientific knowledge as a whole (Gibson & Chase, 2002). Besides, as per Rocard reports 2007, "Inquiry-based science education (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainment levels while at the same time stimulating teacher motivation. However before delving deeper into concepts of inquiry-based science education let's take a glimpse at the historical background of the IBSE methodology by viewing it through lenses of the progress of science education and learning theories through history .

1.2 Learning theories around the world:

Learning Theory describes how students absorb, process, and retain knowledge during learning. Cognitive, emotional, and environmental influences, as well as prior experience, all play a part in how understanding, or a world view, is acquired or changed and knowledge and skills retained.[1,2]

Broadly, learning theories developed around the world have been classified into three major groups. We briefly discuss them and then proceed to discuss how inquiry-based science stems through one of these theories.

Behaviorism: John Watson coined the term "behaviorism." According to him, it is a purely objective and experimental branch of study which deals with the study of prediction of change in behavior in response to some applied stimuli.[3,4] It proceeds through conditioning and the behaviorist arrange the environment to elicit the desired response. Early Intensive Behavioral Intervention, curriculum-based measurement, and direct instruction are some of the educational approaches that have emerged from this model.[5]

Cognitivism: It stems out of Gestalt philosophy which states that prior knowledge must exist to find new connections between pre-existing knowledge and novel information.[6] It emerged as a response to behaviorism and criticized it because it depends too much on explicit behavior to explain learning. Humans are not programmed, and instead, a learner should be treated as a processor of information and view learning as an internal mental process which includes insight, memory, perception and information processing, where the educator focuses on building intelligence and cognitive development.[7]

Constructivism: Founded by Jean Piaget and reinforced through the theories of John Dewey, Maria Montessori, and David A. Kolb[8] constructivism emphasizes the active participation of the learner at all levels of their learning. It proceeds through a shift in cognitive structure by exposition to new information and accommodating it by reaching an equilibrium with their previous understanding of the topic. From Constructivism emerged many models of learning like active learning, discovery learning, and knowledge building, but all of the versions promote the learner's free investigation of the topic within a relatively flexible given framework or structure.[9]

1.3 Science teaching through history and evolution of Inquiry-based learning

The G7 academies of science noted in one of its statements in 2017 how science and technology benefitted many aspects of society. As Edward Teller said "The science of today becomes the technology of tomorrow," so making people aware and teaching them the essential elements of science becomes all the more critical. Science as a discipline has been pursued and taught by people for around 1000 years. That does not mean that science did not exist before it. It is just that formalized approaches and techniques did not exist in ancient times, i.e. science as we know it today. Also, science shifted to focus on understanding different aspects of nature through different ages. For instance, as early as the 1750s, society was predominantly agrarian and thus, most sciences focused on understanding a natural phenomenon (e.g., physics and astronomy) and how it impacted humans. After that human biology and functioning became an important area of research. Then with the 1870 industrial revolution, physics and engineering became all important.[10,11]

However, the reason for pursuing science started getting replaced. Instead of employing science as a tool to understand nature, it was more used to learn about modifying and shaping the world to suit our needs.

By 1900s science was introduced in schools and standardized classroom procedures to be adopted for teaching science started taking form. Most classroom science though focused on being able to memorize and reproduce science facts instead of doing science itself. However, times changed and with it changed, science education. Time and again many revisions to the curriculum were adopted to make science teaching more meaningful and enjoyable for the learner. However, subsequently, it was realized that not just the content, instead of how that content was being taught, was of equal importance if not more. Instead of just drilling and memorization, the focus shifted to doing science. Scholars came up with non-traditional approaches in response to traditional behaviorist approaches for teaching science. Among these approaches, was the "discovery learning" approach which focused on "child-centric" education.

1.4 Statement of Problem

The Indian education system has hardly changed in the past 60 years. Though many efforts have been done by governments and organizations to promote interactive science education in classrooms but the conditions remained pitiable[23]. The same teaching and assessment practices are being used which were instilled at the time of British regime. However, the world has been witnessing a shift in both, teaching and learning method . Among them is an interesting methodology, inquiry based learning, being employed for teaching science to students of all age groups. This methodology prioritizes student questions, ideas, analyses and proceeds through instructor guided, student undertaken investigations. Many different studies have shown the positive impact of inquiry learning methods on the scientific aptitude, learning skills, problem solving, communication and retention of students. More than that, learning through inquiry helps build initiative and self-direction and most importantly lets the student appreciate the inherent rewards of learning. However, not much has been done to implement and accommodate this system of learning in India. The purpose of this study was to formulate a simple IBSE unit (based on 5E model)and try to implement it in a typical government school and India. The focus of this research was to test the efficacy of those methods when employed in institutions with not many resources and what limitations and constraints need to be considered to improve and re-implement the model to enhance the students' learning experience at school.

1.5 What is INQUIRY-BASED SCIENCE EDUCATION?

The National Research Council explains an inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather,analyze, and interpret data; proposing answers,explanations, and predictions; and communicating the results (National Research Council, 1996)[13]

As the name suggests, IBSE is not one single pedagogical method; rather it's a dynamice ever-evolving method of learning which might employ several different approaches and can be implemented in various ways. IBSE is not an algorithm to be followed for teaching science. Rather it presents us with a framework which can be employed to guide the learner through different stages of his/her learning. However, through all of the steps, the learner is actively engaged in either assimilating or accommodating new data through inquiry. This approach establishes some goals but how to go about achieving them depends on the teacher, the learner, the environment and other local factors.

Let us now discuss the key distinguishing elements and goals of IBSE[12] which differentiate it from the mainstream traditional teaching methods. It is not a list of steps to be followed but rather a general framework around which the model can be adapted to suit the context.

- Contextual learning: IBSE draws the content to be taught from the child's environment, not from prescribed textbooks which have a fixed curriculum. The learning is thematic. For example, if a child is to be taught about water pollution and its remediation, then one of the inquiry-based approaches to do this is a visit to a local lake/ pond. The children can themselves interact and find things about the environment which they would otherwise just read from books. They can observe specimen taken from that area, compare it to another specimen, find about techniques involved in gauging pollution and find ways for remediation. This prospect of being able to relate the education imparted, and being able to find the meaning and context to it naturally makes the learner more inclined and interested in the learning process.

- Gauging prior knowledge or background of the learner: Any child is exposed to lots of information since the time she/he is born. They accumulate, assimilate and accommodate information about the things around them. As the constructivist approach suggests that new knowledge develops out of prior experiences. So a learner can meaningfully construct new knowledge, if he/she finds means to relate the novel information, in some or the other way, to his previous beliefs/knowledge/concepts. However, traditional science education approaches hardly encompass methods for gauging the extent of a learner's prior knowledge. This sometimes results in, the learner getting lost along the way and losing interest because they have no way for relating the newly acquired knowledge to the previous one.Another problem is the child might have prior notions or misconceptions about something which if not cleared can lead to conflict which again leads to confusion and ultimately losing interest in the discipline. Thus, it is one of the core guiding principles of IBSE i.e. gauging a learner's previous knowledge before exposing him to new knowledge and trying to help the learner relate the new knowledge to the previous one
- Student's voice: Contrary to the traditional methods which don't encourage student participation rather expects them to be spoon-fed regurgitating vessels going on without any self-motivation, IBSE lays a strong emphasis on student's voice and participation in their learning. Any IBSE program has to ensure that the learner engages with the topic, questions what is taught and are equipped with necessary inquiry skills to find answers to their questions.

  The student's environment has to be conducive enough to make the child confident enough to participate in their learning. Questions must be encouraged, rather appearing to children as a source of embarrassment. Even while assessing the learner, it is important to consider the child's opinion on what was learn and how well. Also while preparing the program student's input can be taken or incorporated into the program, later on. All this makes the learner feel like they are being listened to and they can participate in their learning actively, rather than being passive listeners detached from their own learning.Thus, the emphasis is laid on student participation in all stages of their learning.

- Ongoing assessment: Any pedagogical program/practice once implemented has to ensure that it has sufficient parameters for testing a learners progress. Traditional teaching practices came up with unit based assessment which is administered to students according to some pre-determined schedule. However, how effectively traditional exams (summative assessments alone) can measure the learning or caliber of a student is still a topic of debate. However, IBSE programs have a different kind of assessment algorithm. There are two kinds of assessment: formative and summative assessment. Formative assessment starts at the very onset of the program. It analyses whether the program is designed well enough, is it meeting the learning goals, what can be done to improve the program. This assessment is continuous and ongoing feedback continuously enhances the program implementation. This kind of continuous assessment guides the subsequent learning steps to ensure success at the end of the program. Along with formative assessment which keeps assessing the program as well as the learner's receptivity to it, summative assessments are carried out towards the end of the program . Its goal is to make the teacher as well as the students aware of what knowledge was successfully attained. It helps them analyze their mastery over a topic by comparing it against a standard or benchmark.

1.5.1 Different levels of inquiry

When we talk about inquiring something it can be done at several different levels[14]. Even the purpose of inquiry might not always be the same. The same is true for inquiry in an IBSE program. Depending upon student's age, their learning goals and available resources, IBSE programs usually employ four kinds of inquiry practices which meet different learning goals:

- **Confirmation Inquiry**: This level of inquiry seeks concept reinforcement. The teacher discusses the concept in the class, teaches an experiment that is based on the concept and makes the students aware of the results of the experiment. Now the only thing that remains, for the learner, is to do the experiment and verify the results he/she was taught beforehand.
- **Structured Inquiry**: This level of inquiry goes a step ahead and encourages the learner to self-analyze, evaluate and conclude results to an experiment, the results of which were previously unknown to them. The teacher just comes up with the experiment (and the procedure) about the concept being taught. However the students have to find out the results and conclusions by themselves.
- **Guided Inquiry**: Most of the IBSE program these days employ this level of inquiry. The teacher instead of being a leader assumes the role of a facilitator. Questions about the relevant concepts are posed before the learners, and the learners come up with their own solutions to test or understand the concept. The teacher's role is just to help the students not get too far deviated from the learning goals by filtering the questions and leading the learners towards a fruitful discussion. Hypothesis formulation, experimentation and analysis and conclusion is all done by the learners themselves in the supervision of the teacher as a facilitator.
- **True/Open Inquiry**: This approach to inquiry, though represents constructivist philosophy in its true spirit, is seldom used in IBSE programs due to the natural constraints of time and resource it poses. However, it is not that this level of inquiry is useless to a learner altogether. The most advanced researches and theories are given at the highest levels of all disciplines arises out of true/open inquiry. At the top echelons of any discipline, there are not already available guides and literature, and any new research happens either accidentally or as a result of open inquiry. There is no well-defined direction to the inquiry and the learning goals are not well

defined. The learner comes up with their questions, devise methods of experimentation and analysis and finally communicate their results.

1.5.2 A General framework for scientific inquiry

It has already been about 100 years since constructivist philosophy and child-centric education started garnering support. Since then, many models of education have been given which claim that their learning model is inquiry-based. On the surface, the some models might like simpler or more complex than others, however, they share their core guiding principles which are actually the core guiding principle of IBSE itself. The framework should fulfill the different requirements of science, i.e. should lay emphasis on knowledge of science, science as an investigation, science as a way of thinking, and interaction of science, technology, and society. If we analyze the different IBSE models around the world today (TELSTAR Model, 5 E's approach, Integrating socially model, Action research model etc.) we can see that all of them progress through more or less similar phases of inquiry and those phases can yet again be used to come up with a new model of inquiry tailored around the student's needs

I present the connection between different models through a table adapted from Kathleen Gordon [15]

Inquiry models

Broad Phases of Inquiry	**Integrating Socially***	**TELSTAR***	**Action Research***	**5 E's Model**
Framing and focusing questions	Tuning in	Tune in	Identify the problem/issue	Engage with the topic
	Preparing to find out	Explore		Find what is know and what is to be found
Locating, organizing and analyzing evidence	Finding out	Look	Investigate the problem/issue	Explore the topic
	Sorting out	Sort	Evaluate data	Conduct investigations
Evaluating, synthesizing and reporting conclusions	Going further	Test	List possible actions	Evaluate the findings and draw conclusions
			Select the best action	
Possibly taking action of some sort	Taking action	Act	Implement the action	Elaborate on the findings and conflict resolution.
Reconsidering consequences and outcomes of each of the above phases	Reflect	Evaluate the action		Plan further possible investigations.

Table 1 - Source: Kathleen Gordon, 1999[15]

Let us elaborate on the broad phases through which inquiry progresses:

- **Framing and focusing questions:** Questioning forms an integral part of any IBSE approach. However, questions to be posed and investigated have to be chosen well because questions may or may not lead to a fruitful inquiry. Finding answers to some questions may require some prior knowledge which might be above the cognitive abilities of the students or more generally not the immediate goal of the program. Thus the role of teacher becomes very important as they function as a facilitator to filter "good inquiry questions" and lead the inquiry to a fruitful result/discussion well within the cognitive limits and scope of the program. It is very necessary to know the domains in which the student can be left wandering in as a part of their inquiry which if not handled properly may lead to faulty or untestable hypothesizing.
- **Evidence organization and analysis:** Once a topic/question is chosen for inquiry, algorithmically, the next step is to look at the already available resources/data if any available. It might also be possible that resources directly relevant to the topic of inquiry might not be available /accessible, in which case, the next step is to come up with methods for "relevant data" collection and its analysis. The teacher may need to ascertain and teach the students some concepts or techniques which would be helpful/necessary for the inquiry. Now that the student has the required inquiry skills and all the data has been collected, organizing the data has to be taken care of. The teacher should help the students to record and organize the data into manuals and make them aware of the significance of this organization.
- **Connecting the threads**: After the data has been collected and organized the hypothesis is tested for its validity. The group comes together to discuss their findings and compare the results of their inquiry. Contradictory data needs to be resolved through data recollection and analyzing the inquiry methods employed for their validity. Once the results are consistent some conclusion can be drawn, and further course of action can be planned for instance, what other hypothesis needs to be tested, questioning the sufficiency and accuracy of the data, implications of the finding and thinking about its contextual relevance so that the learning does not just stay confined within books.

- **Communicating the results and furthering the inquiry**: After testing the hypothesis and drawing conclusions, it is also important to report the results so that the inquiry is reproducible by someone else seeking to test the same/ related hypothesis. Communication of results is also important because differentiated opinions lead to criticism which may lead to the framing of further testable hypothesis. If a new or alternate hypothesis has been formed the inquiry phases start over from the first step.

All of the above entities will form an integral part of any pedagogical consideration however each has to be given its due weightage. The traditional educational approaches mostly lay emphasis on two of the above entities i.e. information and problem solving. Thus all of the practices revolve around feeding the student with facts and expecting them to recall those facts in their examination to come up with solutions to problems which hardly have any contextual significance for the student. This leads to confinement of education till the schools and textbooks only. Another problem stemming out of this malpractice is the assessment systems used for gauging the eligibility/potential of a student for a particular discipline. For instance, in India, the IIT's and IISER's use of common standardized examinations for admitting students. However, IIT'S deal mostly with engineering (applied science) and IISER's deal mostly with pure sciences. For engineers, problem solving (related to something known) might objectively be more important than the scientist's scientific aptitude of exploring the unknown. Thus isn't it a mistake to judge students for different kinds of professions using a common standardized examination?

IBSE, on the other hand, owing to its basic tenets not only acknowledges the vital differences between the aforementioned terms but also lays due emphasis on each of it. Different disciplines (and even different topics within the same discipline) may require different dosage of information, knowledge, problem-solving and aptitude for the discipline and any IBSE approach has to ensure that the student gets ample opportunities for amassing information, learning to convert it to knowledge and being able to come up with solutions to problems. Though aptitude is an innate potential or ability but even that can be channelized through proper training and instruction. Only with all of the above in right amount can a learner have the "attitude" required, to become well versed in a particular discipline.

1.5.3 Understanding assessment and role of teachers, students, tests and tasks in assessing IBSE

There is an interesting and well-known research by Budd-Rowe,1970 [16] that shows how extending the wait time (the time teacher waits before rephrasing, hinting or asking an easier question) dramatically increases the quality of student answers. In their finding, the average wait time was 1 sec and increasing it to mere 8-9 secs improved student response. This shows that even a matter of few seconds changes the average class response and thus assessing and questioning isn't to be taken for granted. Technically, the immediate challenge is to ensure reliability without compromising the validity of the assessment. About IBSE, an assessment is only reliable if it is evident that learning is occurring through inquiry and the inferences of the assessment shed light on the scientific understanding and inquiry skills developed among the students.

We briefly discuss some methods of assessment and discuss the two important modes of assessment employed in any IBSE program, i.e. formative and summative assessment.[17]

All kinds of student assessment involve the collection, analysis, communication and use of data for some purpose. All of these phases can progress through multiple kinds of activities however, each will involve.

a) Students involved in some task,
b) The collection of data from that activity by some agent,
c) Analysis of the data by comparing it to some standard
d) Communication of the findings.

There are several forms that each of the components of assessment can take. Different assessment practices and procedures can be developed by different combinations of these various ways of collecting, judging and communicating data.

Comparing formative and summative assessment:

The book by Wynne Harlen,2013 "Assessment and Inquiry-Based science education: Issues in policy and practice" highlights very well the elements of summative and formative assessment. We compare the elements as are stated in the book. I did not think I could do a better job at bringing out those elements so well so I'll be quoting her.

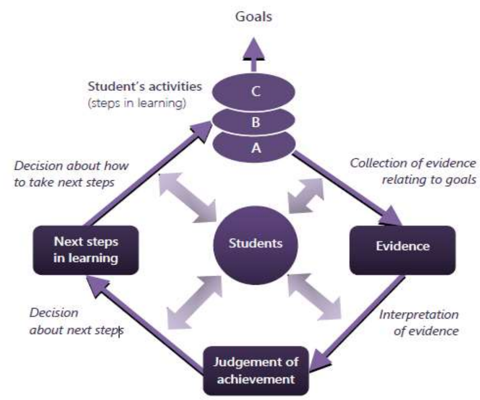


Figure 1:
Assessment for formative purposes *(adapted from Harlen, 2006)*

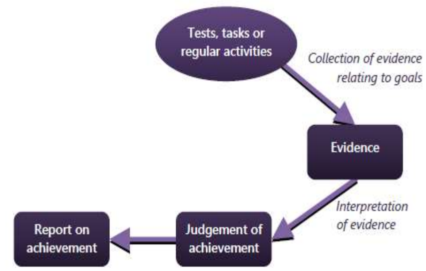


Figure 2:
Assessment for summative purposes *(adapted from Harlen, 2006)*

Key component practices of formative assessment	*Key component practices of summative assessment*
• Students being engaged in expressing and communicating their understandings and skills through classroom dialogue, initiated by open and person-centred questions • Students understanding the goals of their work and having a grasp of what is good quality work • Feedback to students that provides advice on how to improve or move forward and avoids making comparisons with other students • Students being involved in self-assessment so that they take part in identifying what they need to do to improve or move forward • Dialogue between teacher and students that encourages reflection on their learning • Teachers using information about on-going learning to adjust teaching so that all	• Students may be involved in special tasks or tests as part of, or in addition to, regular work • Takes place at certain times when achievement is to be reported, not a cycle taking place as a regular part of learning • Relates to achievement of broad goals expressed in general terms rather than the goals of particular learning activities • Involves the achievement of all students being judged against the same criteria or mark scheme • Requires some measures to assure reliability • Provides limited opportunities for student self-assessment

Fig 1 Source: Assessment and inquiry-based science education, Wynne Harlen, 2013

This highlights well the difference like two assessments and lays due emphasis on the needs of both.

The above text summarizes IBSE and its elements and gives an idea about the framework of learning suggested. This conclusively leads to studies on the actual effectiveness of inquiry-based learning methods on students of different age groups and the different schools of thought existing regarding IBSE.

1.5.4 Studies on the effectiveness of inquiry learning methods and difference of opinions

As happens with most theories here too we have different schools of thought on inquiry-based learnin, and disputes have been going on for the past 50 years. (Ausubel, 1964; Craig, 1956; Mayer, 2004; Shulman & Keisler, 1966). One side argues that students learn best in the unguided environment and they must discover knowledge on their own (e.g., Bruner, 1961; Papert, 1980; Steffe &Gale, 1995). The other group is in favor of direct instruction and believes should not be left to discover knowledge for themselves (e.g., Cronbach & Snow, 1977; Klahr & Nigam, 2004; Mayer, 2004; Shulman & Keisler, 1966; Sweller, 2003) Hmelo-Silver, Duncan, & Chinn cite several studies which are in support of the constructivist problem-based and inquiry learning methods. For example, a project called GenScope, an inquiry-based science software application. Students using the GenScope software showed significant gains over the control groups, with the largest gains shown in students from basic courses.[36]The approach has been considered capable of promoting motivation among secondary schools students by creating interest in the process of acquiring scientific knowledge and skills (Gibson and Chase, 2002).

Students' academic motivation stems from their tendency to find academic activities meaningful and relatable and to try to derive the intended academic benefits from the teaching and learning process (Dowson and Mclnerney, 2001). High academic motivation has mostly been linked improvement in students' academic achievement (Kushman, Sieber and Harold, 2001).

According to Nuangchalerm and Themmasena (2009), inquiry-based learning activities promote cognitive and analytical thinking, and learning satisfaction in students. “Learning is not the lonely act of an individual, even when it is undertaken alone. It is the matter of being initiated into the practices of a community, of moving from legitimate Peripheral participation to centripetal participation in the actions of a learning community”(Lave and Wenger, 1991). The classroom is a very appropriate place where students interact with each other and also with the environment and learn how to “communicate the results” (National Research Council, 1996). “Reviewers of the cooperative learning literature have long concluded that cooperative learning has its greatest effects on student learning when groups are recognized or rewarded based on individual learning of their members"

(Slavin 1996). When the program calls for student participation at all levels of their learning, they experience a sense of urgency and responsibility for their learning. Thus the approach reinforces itself for greater student motivation and engagement. (Ryan & Deci, 2000).

Criticism

Reviewing of literature regarding effectiveness of constructivist model led some researchers to conclude that constructivists often cite each other's work. However empirical evidence is not cited(Kirschner, Sweller, and Clark (2006))[18.]

Richard E. Mayer from the University of California, Santa Barbara, wrote in 2004, that there is sufficient evidence to make one skeptical about the benefits of inquiry learning. He reviewed research on the discovery of problem-solving rules culminating in the 1960s, the discovery of conservation strategies culminating in the 1970s, and discovery of LOGO programming strategies in the 1980's. In all cases, the guided discovery was found to be more effective than pure discovery in helping students learn and transfer.

Another criticism for the inquiry learning approach is based on the memory structure, and it has direct implication for instructional design((e.g., Sweller, 1999; Sweller, van Merriënboer & Paas, 1998).) The researches skeptical of the inquiry learning methods argue that problem –based searching puts a heavy load on working memory and while the working memory is busy in searching solutions to the problem it cannot be used to learn.((e.g., see Sweller,Mawer,&Howe, 1982).) Well-designed, controlled experimental Studies like(e.g., see Moreno, 2004; Tuovinen & Sweller, 1999) provide stronger evidence for supporting direct instructional model. Some researchers noted that when learning occurs with pure-discovery methods and minimal feedback the students often become lost and frustrated, and their confusion can lead to misconceptions.(Hardiman, Pollatsek, and Weil (1986) and Brown and Campione (1994)).

In accordance with theATI findings and the expertise reversal effect, Roblyer, Edwards, and Havriluk (1997) reported that teachers concluded inquiry learning to be fruitful only if students had some pre-required knowledge of the topic and underwent some training for the necessary inquiry skills pertaining to the topic.

Conclusively , we can say that inquiry learning has been found to be effective if the inquiry is somewhat structured so that students are not under too much pressure to just find novel information rather it has to be in accordance with their prior expertise and whenever necessary direct instruction and scaffolding must be resorted which decreases the cognitive load on the student by suiting and adapting the model to their prior knowledge and experiences.

Chapter 2

2.1 Science education in India

"In the post-independent India, our constitution adopted the goals of establishing the society based on the scientific temper, humanism and spirit of inquiry. It enshrines in Article 51 A(h) of the constitution that it is the fundamental duty of every citizen of the country to inculcate, propagate and further disseminate the scientific temper in society. India is the only country in the world that has adopted such an obligation in the written constitution."

Scientific thinking is a value developed in humans after long sought struggles of man against the culture of fear and constraints. The science education policy of India is based on the recognition of the above fact. It is as important as the individual living in the society for the individual and the society to progress and attain its moral, social, spiritual and material goals. However, in the recent decades, it has been seen that there is a retreat of public reasoning in the public sphere that has helped in the culmination of and rise of anti-science attitude and religious revivalism in public life (Raina, 2016). National Council Education Research & Training (NCERT) Position Paper on science[5] has recognized that the science books are overloaded with facts instead of concepts. Sarangapani[23] comments on the pitiful condition of science teaching in classrooms. She states that as a nation we might take pride in the success of our science graduates abroad, but we have neglected and not laid due emphasis on classroom science learning and teaching. Another major problem is the authoritarian nature of science teaching in India which yields no space and flexibility to the teachers and learners. It adheres to an absolute and strict interpretation of textbooks in the classrooms[24].

In 1964, the Indian Education Commission chaired by Dr. Kothari stated that the condition of science education in India is pathetic and we have failed to catch up with the explosion of knowledge in science. To cater to this urgent need projects were launched to improve and upgrade school curriculum and textbooks. Among those projects was a National Policy of Education(NPE)[25] launched to connect the development of citizen's education, their science education and development of the nation as a whole. The policy was linked to increasing scientific awareness, temper and literacy in the country and producing the skilled workforce needed for the economy. However, this had some negative impacts because textbooks were loaded even more with information on the pretext of knowledge explosion. This increased the load on students even more.

In the 1970s, science educators, independent resource groups, and educationists decided to come together to confront the dogmas of Indian school science and offered to collaborate in formulating an approach that shifts emphasis from textbook-centric to learner-centric approach. Hosangabad Science Teaching Program (HSTP) was one of those program started in 1972.

Kala and Ramadas[26] reviewed the shifting trends in science education from behaviorism to constructivist methods based on the work of Piaget and others.

"However, Kala & Ramadas[26] state that unfortunately, the practices of science education research and curriculum making these developments in domain-independent science education research like epistemology studies, cognitive psychology is still to be seen in India" [21].

An article[19] by Padma M. Sarangapani,2014 highlights the three practical challenges faced by science education India. The first is the most basic and long-persisting problem of the school labs not being well equipped due to our inability to provide them with the necessary resources for the same.

The second challenge is a shortage of science teachers and primary level teachers who have a science background at least till class 12. This might lead to lack of confidence and competence in the teacher's knowledge of science and mathematics which has serious implications on the learning when those teachers(primary level) are asked to teach all subjects. Specialization is not sought for at the primary level. People also get discouraged from pursuing science further because of a lack of scope and its financial unattractiveness in India. The third challenge facing us is regarding what should be included in the science curriculum, how the education can move away from a “subject approach” to “discipline approach” and how it can be made relevant to suit the student’s aspirations, their view of life and future.

2.2 Student’s attitude towards science education

The first India Science Report (Shukla, 2005) informs on the attitude of student’s relating to science and their career choices[20]. The report finds that mathematics was the most preferred subject(30% of students in class 6-8 rating it as number one). As for Physics, Chemistry, and Biology, only 10% of students rated them as top subjects. This figure triples if we look at the top-rated subjects by students of class 11-12. This shows a dramatic increase in interest in science subjects at higher levels of education.

However, when analyzed the satisfaction level of students regarding their science teaching there is a stark difference. Around 66% of students of class 6-8 feel satisfied with their science teaching, but this figure drops to around 40% for students of class 11-12 who were satisfied with their science teaching. This is quite ironic and a serious problem for our system in which the students’ interest in science at higher stages increase, accompanied by a general dissatisfaction regarding the science education they are being provided.

The Department of Science and Technology(DST) has launched programs and schemes lie KVPY(Kishore Vaigyanik Protsahan Yojna) and INSPIRE to encourage under-graduate and graduate students to pursue career in science. A centrally sponsored 'Scheme for Providing Quality Education in Madrassas', launched in 2009 by the National Institute of Open Schooling to in to bring madrassas and maktabs up to the standard of the national education system. Also, the Jawaharlal Nehru National Science Exhibition, science museums, events of the National Children's Science Congress, National Science Day, etc. are all attempts to inculcate scientific fervor, temperament and scientific aptitude in students and attract young minds to pursue science. The current formal system of education, however, does not espouse the exploratory way of learning science (Indian National Science Academy, 2001).

2.3 Efforts for promoting Science education in India

"Arvind Gupta led a movement in science education by enabling children to experience the connection between science and life through small science activities and construction of toys from locally available materials. Anveshika is another initiative of the Indian Association of Physics Teachers that creates centers across India in schools and colleges where students and teachers can learn experiment-based physics and try out their own ideas. They organise interaction sessions with students, short and long term teacher-training programmes; develop new teaching demonstrations and other activities. The Agastya International Foundation, a non-profit organisation, whose mission is to develop scientific inquiry for economically disadvantaged children and government school teachers, has created 125 Mobile Science Vans which take science education to the village doorstep, 45 Science Centers for disadvantaged children, 260 Night Village Schools, and 108 science laboratories." [28]

2.3.1 NPE(National Education Policy) and NCF(National Curriculum framework)

The National Curriculum Framework (2005) acknowledges the 'product' obsession of school science and has recommended a move towards the weakening of disciplinary boundaries and linking school knowledge with learners' context as the avowed goals of school science education[27]

National Curriculum Framework Policy (NCF) 2005 of India recommends teaching science as a process/inquiry and value system so its important for us to discuss the NPE principles and the tenets of NCF,2005 to get a firmer grasp of what kind of inquiry NCERT suggests and how to streamline the school curriculum to meet the objectives put forward. The NCF draws its policy basis from the 1986-92 NPE(National Policy on Education), focus group discussions etc. For details regarding the same refer NCF,2005.[27]

2.3.1.1 NPE guiding principles:

• Connecting knowledge to life outside the school
• Ensuring that learning is shifted away from rote methods,
• Enriching the curriculum to provide for the overall development of children rather than remain textbook centric,
• Making examinations more flexible and integrate into classroom life and,
• Nurturing an over-riding identity informed by caring concerns within the democratic polity of the country.

NPE suggestions:

- Teachers more accountable, and the schools more autonomous and responsive to the needs of children.
- Stimulate questions and entanglements with local physical conditions, life, and environment.
- Curriculum design requires a careful study of children and an understanding of what they are capable of learning at different ages
- 'Child-centred' pedagogy means giving primacy to children's experiences, their voices, and their active participation.
- The context in which learning takes place is thus of direct cognitive significance.
- If children's social experiences are to be brought into the classroom, it is inevitable that issues of conflict will need to be addressed. To use conflict as a pedagogic strategy is to enable children to deal with conflict and facilitate awareness of its nature and its role in their lives.[37]

2.3.1.2 NCF 2005

Deciding the curriculum is an important factor in realizing the national aspirations as well as the needs of the learners. Curriculum design encompasses the validity of it, the learning goals planned and devising methods for its implementation. The NCF gives a few basic criteria to determine the validity of a science curriculum:

- *Cognitive validity- Whether the topic being taught is well within the reach and grasp of student, and they are equipped with the necessary tools for understanding that topic.*
- *Content validity- Whether the topic being taught is up-to-date with the current research, and there are no loopholes or fallacies in the content.*
- *Process validity- Whether the method and practices being used in learning are correct/tested and are in line with the societal and community norms.*
- *Historical validity- The student should appreciate how a specific theory came to be, as it exists and how things change through time.*
- *Environmental validity- The students have to be made aware and conscious of the environmental ethics, and the curriculum too should aim to foster the same instead of encouraging practices that pay no heed to the environment.*
- *Ethical validity- The students are being encouraged to use fair means to progress in their lives.*

The NCF provides a few guidelines that can help structure the student curriculum. It's a flexible framework which yields due autonomy to the learner and teacher. A brief discussion of the curriculum structuring will bring out the method NCERT recommends for the same.

- **At the primary stage**:

  Objectives:

  The child should be engaged in exploring the world. With it.

  Nurture the curiosity of the child about the world (natural environment, artifacts, and people)

  Engage in exploratory and hands-on activities for acquiring basic cognitive and psychomotor skills through observation, classification, inference, etc.

Throughout the primary stage, there should be no formal periodic tests, no awarding of grades or marks, and no detention.

- **At the upper primary stage**:

  Objectives:

  The child should be engaged in learning the principles of science through familiar experiences, working with hands to design simple technological units and modules.

  Group activities, discussions with peers and teachers, surveys, organization of data and their display through exhibitions

  There should be continuous as well as periodic assessment (unit tests, term-end tests). The system of 'direct' grades should be adopted. There should be no detention.

- **At the secondary stage**

  Objectives:

  Students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological modules than at the upper primary stage. Systematic experimentation as a tool to discover/verify theoretical principles, and working on locally significant projects involving science and technology, are to be important parts of the curriculum at this stage.

- **At the higher secondary stage**

  Objectives

  Science should be introduced as separate disciplines, with emphasis on experiments/technology and problem-solving.

  The curriculum load should be rationalized to avoid the steep gradient between secondary and higher secondary syllabi.

  The tendency to cover a large number of topics of the discipline superficially should be avoided.

Following the guidelines of the National Curriculum Framework (2005), textbooks have been revised to incorporate ample inquiry opportunities for students. It is assumed that teachers using these textbooks center their pedagogical approaches around inquiry. However, research indicates that even when using inquiry-based science curriculum materials, elementary teachers may not always effectively engage students in science as inquiry (Forbes & Davis, 2010; Appleton, 2002; Pine et al., 2006). Furthermore, on the recommendations of NCF (2005), assessment practices were revised and continuous and comprehensive Evaluation is implemented in all the schools managed by the Central Board of Secondary Education (CBSE) since 2009.It discourages teachers from resorting to simple written tests rather use diverse and authentic methods of assessment. However, Nawani (2013) notes that school-based assessment practices are still hitched onto behaviorist traditional forms of content-based paper and pencil tests.[28]

So basically, we conclude that many efforts have been done by the government and various NGO's to promote inquiry-based science education in India. However, a discussion is needed on the actual implementation of those techniques and how successful have we been in the context of improving science education and teaching in schools. A case study taken from Indian Educational Review highlights teacher's views on IBSE in India.

2.4 **A case study taken from Indian educational review**

The study adopted a multiple case-study designs (Holliday, 2007) to understand pedagogical processes associated with the teaching of inquiry-oriented environmental studies curriculum. The context of the study and methodology details can be found here.[28] This study[28] highlights the position IBSE holds in India as of now. The participating teachers taught in government schools run by the Delhi Government.

Summary of findings and some narratives recorded during the study[28]:

Although inquiry offers compelling opportunities for science learning, it emerged from the study that there are many challenges to the successful implementation of inquiry-based learning. The challenges are described below.

• Non-synchronisation between inquiry-oriented curricula and assessment practices: According to the teachers though textbooks prescribed the inquiry approaches; however the assessment has not been modified to include inquiry, and this hampers the implementation of inquiry even while teaching. Therefore, teacher A suggested that she "will not take the risk of spending time in the inquiry which may hamper student achievement."(Pg 30) Also, "teaching of science was somehow correlated by the teachers with students' taking up of entrance examinations for entry to higher educational institutes of medical and engineering professions which often includes the curriculum of both classes XI and XII." In teacher B's opinion, "*Science ka content yard Karne ki aadat Nahin hogi to age kya karenge, aage entrance bhi to deni hoti hai*".Thus, here an unacknowledged emphasis on rote memorization lurks beneath the shadows of a faulty implementation of inquiry-based teaching.

• The conception of science and science teaching: "Teachers seemed to be adhering to John Locke's conception of tabula rasa", i.e. taking science to be a collection of facts that can ably be passed only from an expert to a novice . Teacher B argued, "*hume bhi to aise hi padhyi gai thi science*", suggesting that they had been taught science through lecture method which has reaped gains in terms of professional growth. Thus the teacher's personal bias could also be a reason for half-hearted implementations of inquiry-based approaches. Also it is to be noted that time constraints for the inquiry approaches pose a difficulty in its implementation. The teachers believe that, "that time" can be better spent on covering the "prescribed syllabus".

• Accountability pressures: The teachers are under pressure by the parents and the school administration as is evident form their argument that both, school authorities and wards consider direct lecturing time better spent than “extra-curricular science inquiry” . The ‘additional’ time needed to engage in inquiry is perceived as less efficient when compared with lecturing about science concepts. So this unwanted and illogical accountability pressures add up to the discouragement of inquiry-based approach implementation.

• Perceiving inquiry as elitist: Some teachers were also of the belief that inquiry requires lots of resources as it is not targeted and requires “playing around with things”. All the more, inquiry-based science practices were linked to students’ socio-economic backgrounds and their possible prospects. The following interview transcript (quoted from the study) with Teacher C elaborates it.

T (Teacher): Madam, ye sab in bachon ke liye nahin hai…

Rr (Researcher): Ye sab kya?

T : Ye inquiry…inhe koi scientist nahin banana… inhe to rickshaw wala hi banana hai…uske liye kaun si inquiry chahiye… ye to un bachon ke liye hai jo bade public schoolon mein jate hain jinko age chalkar scientist banana hai…. (pause)…unnnn…aur saman kahan se laoge aap bataiye (This inquiry…these children will not grow up to become scientists, rather they will become rickshaw pullers only…. which inquiry is required for the profession of rikshaw pulling, tell me… all this is for students who go to big public schools and may grow up to become scientists in the future…unnnn….. (pause)…from where will we get stuff for inquiry-based activities?)

Rr : Aapko kya lagta hai saman ke bina inquiry nahin ho sakti ?

T : batao na kaun sa experiment kar sakte ho?

Rr : Maine kitab dekhi thi…usme kuch surveys, discussions, sinking-floating jaise experiments diye the…kya nahin ho sakte? (I have seen some forms of surveys, discussions, sinking-floating 32 Indian Educational Review, Vol. 55, No.1, January 2017 Teachers’ Perception of Inquiry-based Science Education... experiments were given in the textbook… can they not be done?)

T : Mushkil hai….ye tik ke to baithte nahin hain aur (emphasis in tone) kya hamein koi assistant mila hai yahan (It seems difficult…. these students do not have etiquettes to sit properly in classrooms… and have we got any assistant to help us out?)

Rr : acha, assistant mile to phir…(Ok, if you get an assistant then…) T : (irritated sound) dekhenge tab…(We will see then…)

It emerges that although teachers believed that they are engaged in inquiry-based science education since they voluntarily participated in the study yet they lacked confidence in conducting an inquiry. They assumed scientific inquiry to be related to one's socio-economic backgrounds and particular professions of science only. Another constraint in carrying out inquiry-based science education was their perception that scientific inquiry demands lots of manpower and infrastructural resources.

INFERENCES

1. Though teachers voluntarily participated in the study and also believed to be following inquiry approaches; however they were hesitant and lacked confidence in conducting an inquiry.
2. Scientific inquiry is equated to a child's socio-economic background and considered important for specific professions only(E.g. "scientist")
3. Another limitation which was well evident was the shortage of resources, manpower and time.

This article made me think about how difficult can it be implementing inquiry-based learning methods in a government school. So I inquired and found a government school in Manauli, Mohali, Punjab. According to a Tribune article, the school was to be inducted with smart learning so I inferred it to be a progressive school and decided to employ the 5E's inquiry learning model there and check for any actual improvements in students' performance and the limitations/constraints of employing the inquiry learning method in a government school.

Chapter 3

3.1 Aim of the study

This study was designed to test the effect of Inquiry-Based Teaching (IBT) approach on government primary school students' achievement in the learning of physics based on the topic Heat and Temperature.

3.2 Objectives:

- To test any actual benefit of IBT over RTM
- To test whether IBT leads to increased interest and motivation in the discipline.
- To test whether IBT yields any considerable improvement in the science communication skills of the student.

3.3 Considerations for the study:

- The school chosen had to be a government school because we wanted to test whether inquiry can be fruitfully conducted with minimal resources.
- We wanted to test the methodology on students who had no prior experience of interactive forms of teaching like IBSE.
- We identified that students of class 9,10,11,12 are mostly busy in their examination preparations and hardly wish to do anything that deviates from their immediate academic focus, so we chose class 7 as our testing group.
- The unit chosen to be taught through inquiry was identified to be "Heat and Temperature." Reasons for choosing this topic was that the activities were simple, children can easily relate to the topic because of so many experiences with heat, and they can also find real-world implications of studying the topic.

3.4 Hypothesis of the study

To achieve the objectives of this study, the following null hypothesis was tested at a significance level of alpha equal to 0.05:

Ho1: There is no statistically significant difference in students' achievement in learning Magnetic Effect of an Electric Current between students' taught using IBT approach and those taught using the Traditional(Regular)Teaching Methods, TTM/RTM.

3.5 Conceptual Framework of the model employed

The inquiry framework utilized for this study was based on Bybee's 5E learning cycle model[29] which is an Inquiry-Based Teaching (IBT) approach model (Llewellyn, 2005). The 5 E-learning cycle weaves together learning experiences to give the students the opportunity to construct their knowledge and understanding of the concept during all stages of their learning.(Bybee, 2002).

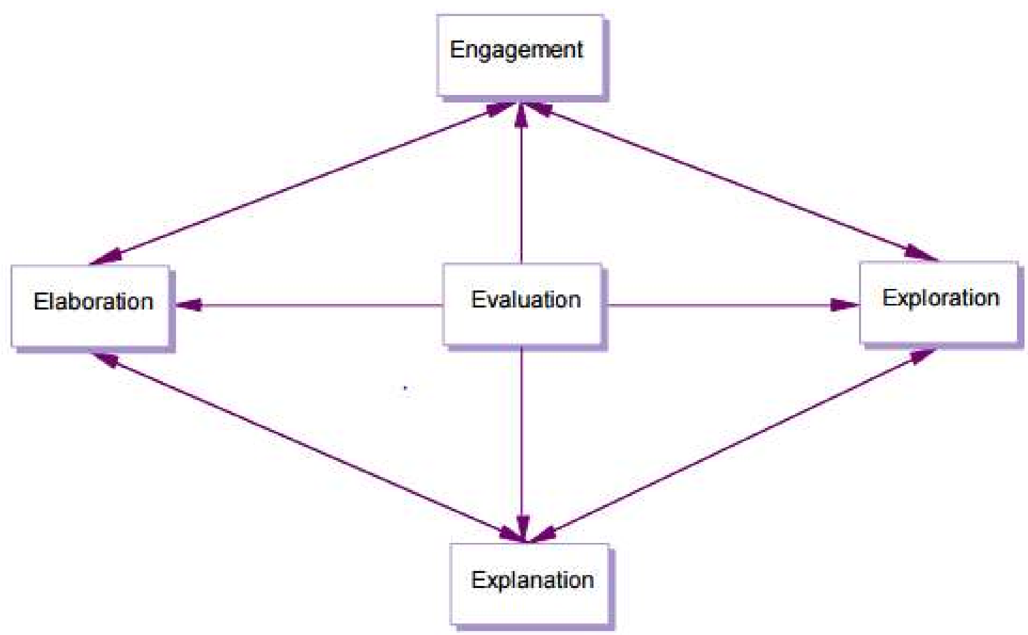


Fig 2 The 5E instructional model (source: L B Duran[30])

Bybee (1997) declares that "using this approach, students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment. Learners interpret objects and phenomena and internalize those interpretations in terms of their current conceptual understanding" (p. 176).

In the engagement phase, the teacher tries to capture student interest and imagination regarding the topic to be taught. This phase provides an opportunity for the teacher to gauge the student's prior experiences and knowledge about the subject (Bybee, 2002). In the exploration phase students interact with materials and ideas through classroom and small group discussions (Llewellyn, 2005). This instills a common set of skills and knowledge among all the students so that they can equally take part in discussion with teacher and classmates. In the explanation phase students are provided an opportunity to connect their prior knowledge to the knowledge at hand and make conceptual sense of the main ideas. This phase also provides the opportunity for the introduction of formal language, scientific terms jargon that might make help students' express their prior experiences better and more easily. In the elaboration phase students' are provided with the opportunity to apply introduced concepts to new experiences (Llewellyn, 2005). This phase helps students to make conceptual connections between new and prior experiences, connect ideas and deepen their understanding of concepts and processes. The evaluation part which has been centrally placed in the 5E model takes place through all phases of the inquiry(Bybee, 2002).

In the engagement phase, the teacher captures students' interest and makes them curious about the topic and concepts to be learned. This phase provides an opportunity for the teacher to find out what students already know or think they know about the topic and concepts to be developed (Bybee, 2002). In the exploration phase, students interact with materials and ideas through classroom and small group discussions (Llewellyn, 2005). This helps the students to acquire a common set of experiences so that they can compare results and ideas with their classmates. In the explanation phase students are provided an opportunity to connect their prior experiences with current learning and to make conceptual sense of the main ideas. This phase also provides the opportunity for the introduction of formal language, scientific terms and content information that might make students' prior experiences easier to describe. In the elaboration phase students' are provided with the opportunity to apply introduced concepts to new experiences (Llewellyn, 2005). This phase helps students to make conceptual connections between new and prior experiences, connect ideas and deepen their understanding of concepts and processes. In the evaluation phase that is centrally placed in the model and takes place virtually in every phase of the 5E learning cycle model provides a summative assessment of what students know (Bybee, 2002).

3.6 Context of study

Manauli has a significant presence of migrants working as traders, artisans, carpenters and in other un-organised sectors. The Census of 2011,GoI reports the literacy rate in Manauli to be around 80%. Manauli has a primary and Smart Higher secondary school which has more than 800 students enrolled from the nearby villages of Mauli, Chilla, etc. I chose the Government Senior Secondary School,Manauli for the purpose of my study. According to the Tribune article[31] its reported that the school was converted to a smart school run by government, on 30 January 2019. The article further states "Sidhu said the state government was converting several government schools into smart schools with an aim to uplift educational standards in the state. District Education Officer (senior secondary) Himmat Singh Hundal said the school was selected based on its past five-year record in education, sports, and other extra-curricular activities. "The school is equipped with facilities such as eco club, social science club, and maths club," the DEO said."[31]

I chose class 7 for my study. The school had two sections each with 20 students. The medium of instruction at the school is predominantly Punjabi. Some students use English medium NCERT books too, but most resort to the Punjabi medium NCERT. Through conversations and interactions during the session, it was found that the students were quite less proficient in English speaking and writing. They could read English satisfactorily though. Some students were wards of local farmers while some of the migrants who have settled in and around Manauli . Most of the students seemed to belong from the upper lower class and lower middle class families. Some had smartphone access at home but most of them were unfamiliar to the internet.

Section B had eight girls and 12 boys, while section A had nine girls and 11 boys. On enquiring, it came to light that the students had already studied the topic Heat and

Temperature. So a test was taken to test their prior knowledge. We call it to test 1. After both, the sections had been administered their respective sessions. Another test was taken to test the improvement. We call it to test 2. However all 20 students of each class did not take both the tests. After eliminating those and a few answer sheets which seemed dubious(copied), we are left with 13 students in each class who gave both the tests.

3.7 Methodology and implementation

As the pedagogical approach used for both sections was so different so each section needs a separate discussion of how the sessions were carried out. We also discuss the adaptations that had to be made to suit the 5E model to the students of the school.

Section B

This was the control group. The control group was taught the topic Heat and Temperature through traditional teaching method of transmittance. I proceeded according to the topics in their book. Total three sessions, each 40 min long, were taken. The first session was spent teaching them about the differences in heat and temperature and making them understand the use of temperature as a measure of heat. Also, the concept of thermometers as a device to measure temperature and indirectly heat, was introduced. In the next session, I taught the students about different kinds of thermometer and the need for both. Then we came to the topic of transfer of heat. Through various examples I taught them how can we see that heat is being transferred and what is the method of transfer . We discuss conduction and convection through different examples taken from their book and some real-life examples I chose to let the students feel familiar with the concept. The next session was utilized in teaching the students about radiation by taking sun as the primary example. Then the environmental implications of heat transfer were discussed by taking sea and land breeze as an example. Then we discussed some real-life implications of heat and its transfer by taking examples like conductors and radiators, what kind of clothes suit in what climate, etc. This sums up the sessions for the control group.

Evaluation

The section was administered a test before the session(Test 1) and one test after the session(Test 2). The same test was also administered to the other section.

Both tests had ten questions each with some questions having two parts which have been allotted half marks each. Both tests were of 10 marks each with a partial marking for right answers.

Section A

Section A was taught the topic Heat and Temperature using the 5E model.

The first session was mostly utilized in **engaging** the students with the topic. I asked them several questions to ignite their imagination regarding the topic. The students also contributed to the questions. All the questions which were raised were noted down. The questions which were planned to be answered during the sessions (inquiry questions) were separated and the outlier questions were answered briefly on the spot and the students were encouraged to pursue it further if it interests them. The inquiry questions were sequenced in a way that logically introduced the concepts to be covered one after another in a progression.

In the second session, to begin the inquiry and **explore** the topic we started with a simple question "If we place a wooden and iron piece in the sun for the same time, which will feel warmer? Will, anyone of them, actually be warmer?" . The best way was to conduct the investigation and let the **explanation** emerge. So it panned out into an activity and the students came to know the answer to the first part of the question raised. However, the second part still remains unanswered. For that I introduced the concept of the thermometer as a device to measure the heat content of a body. The students measured the temperature of the wooden and iron piece and concluded after some minor debate that the temperature of both were equal.

Now that the students know about heat temperature and thermometer the logical progression was to teach them about different thermometers and their respective use. The third and the fourth session was utilized in teaching the students how to read a thermometer, precautions needed while handling one and how to differentiate thermometers. The lab of the school was not well equipped, and they had only one clinical and a few laboratory thermometers. So the students were divided into groups for this activity and the equipment was passed around. This process consumed unnecessary time.

The fifth and sixth session introduced the concept of heat transfer. For initiating the relevant inquiry, I made the students watch two videos[32,33].I would like to clarify that this video was not pre-decided; rather, the students were found deficient in knowledge of the topic to conduct any fruitful inquiry. So a basic scaffolding in the form of this video was planned after judging the prior knowledge of students about the topic. This differentiates inquiry learning from content/activity based learning where the framework proceeds according to the existing skill set and knowledge base of the student and adapts to suit it.[34] While content based learning focuses on teaching scattered concepts through activities, IBSE focuses on giving the child a sense of progressing through the investigation by gaining new information, assimilating it and accommodating novel information when faced with one. Various questions were raised regarding the videos. Actually the activities on the video couldn't be carried out because of the school lab being ill-equipped and there wasn't a feasible way to conduct the activity for 15 students. This is where I had to introduce some scaffolding in the model and actual hands-on investigation could not be carried out by the students.

The seventh and eight sessions were utilized in discussing the real world implications of heat transfer. It included discussions relating to sea breeze and land breeze. I had asked a question in test 1 and I decided to carry out the activity to let the students discover the answers. He question was " which feels warmer: A thick coat or 2 thinner sweaters?"

The students carried out the activity and I modified the activity to also include reflection and absorption of heat by different colors. So the students tried on different color coats and sweaters and could finally conclude the sweaters feel warmer. Through this activity was introduced the concept of insulation and the students could appreciate why they got an unintuitive answer to that question.

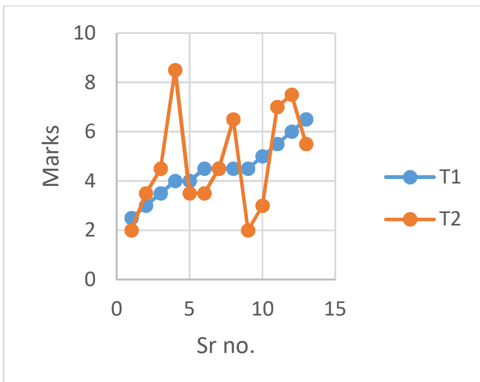
These sessions required more scaffolding than planned because of some limitations which we will discuss further in the study.

Evaluation

Apart from the tests administered to both the sections this section also underwent formative assessment through personal observation through daily-basis interaction and the way the students carried out the activities and investigations.

3.7.1 Findings and results

- The student's individual performances in test 1 were arranged in ascending order and their corresponding marks in test2 have been mapped section wise to compare the individual improvement



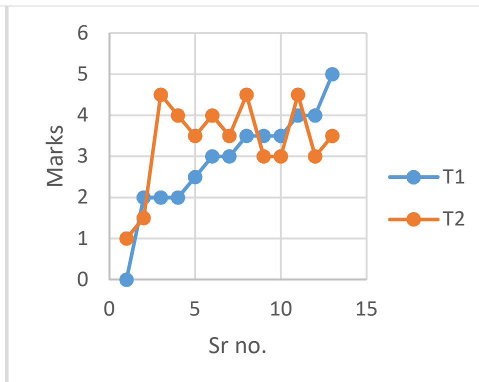
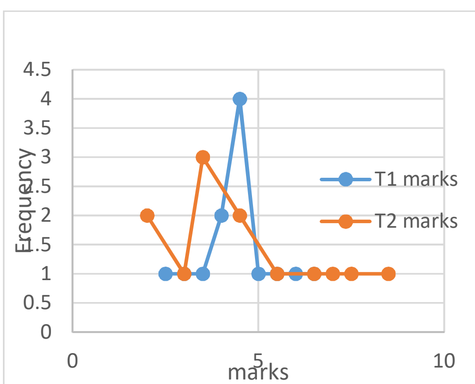


Fig 3. Control batch **Fig 4. Experimental batch**

- The frequency of scores was mapped to see the spread.



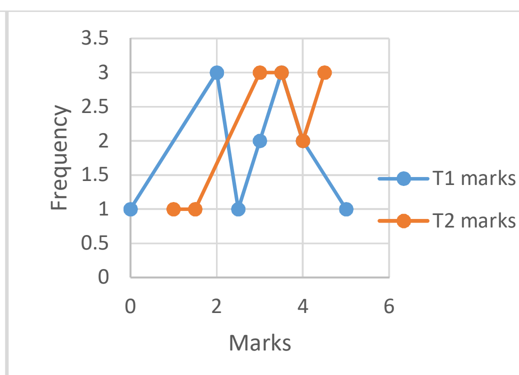


Fig 5. Control batch Fig 6. Experimental batch

- Cumulative scores for the two sections in 2 tests are shown below: MM refers to maximum marks.

	Test 1 (MM: 10)	Test 2 (MM: 10)
Control batch	**58 (4.6)**	**61.5 (4.7)**
Experimental batch	**38 (2.9)**	**43.5 (3.3)**

Table 2. Average and cumulative marks obtained for both sections

- For testing that both the batches belonged to the same sample population, we conducted a two-tailed t-test (on marks obtained in test 1 by both the sections) which gives a p-value of 0.003. This shows that the samples were significantly different, so there is no point in conducting the test for improvement in test 2. This fact might have lead to warping of the results of the experiment because the samples being tested did not belong to the same population, to begin with.
- For testing the improvement happening through traditional teaching method and IBSE, we compare the improvement of students of both the sections. On conducting a two tailed-t-test on the improvement of two sections in their respective test 1 and test 2 we get a p-value of 0.8. This tells that we can say with 80% confidence that both sections had a similar improvement irrespective of the method used for teaching.

3.7.2 Inferences

- The F2 graph for the experimental batch shows that students who had performed below average in test 1 performed well post the IBSE sessions in test 2.
- The spread in the graph F4 shows that the knowledge base of students has become more uniform because marks lie in a lesser range.
- Both sections show an increase in total score before and after the respective sessions but the increase not significant in case of either. A fact that might lead to warping of results is that the test 1 scores for both sections should have been comparable, but there is a significant difference between the two which suggests that the experimental batch was deficient in knowledge of the topic than the control batch before they were subjected to any sessions. It might have resulted from another practice of segregating students on the basis of their performance in schools.[35]

- Another reason that may have resulted in a non-significant increase is the way the model was implemented. Sufficient investigations could not be carried out regarding each topic due to material and time constraints. Extra scaffolding also had to be resorted to when I felt the student's inquiry was not going in the right direction and students did not have enough prior knowledge regarding the topic. This might also have resulted from the in-exhaustive evaluation of how the students were faring during the session because the formative assessment was mostly through verbal interactions in which language proved a major barrier.

3.7.3 Qualitative results

1. The tests were subjective so students also answered some questions partially or partially correct at times. On analyzing those numbers, we see an increase in the number of partially right answers for experimental batch which shows that their thought process has improved and they can think and relate to questions from real life context if not fully then at least to some extent.
2. After the session for the experimental batch was over the students expressed a desire to bring some models they had built previously for some event and discuss them in class however there final term exams were starting so that session did not happen. However, the interest in learning through activity is a positive change in the mindset.
3. The student population there was mostly Punjabi speaking and so was the mode of learning. Most of them answered the test question too in Punjabi. However, in test 1 the experimental batch was observed to use casual language in answering scientific questions but in test 2 some of them resorted to using scientific terms which is a positive improvement in their skill of science communication.

3.7.4 Limitations of the study

1. As stated above, the student population resorted to Punjabi (though they understood Hindi and some of them even translated the things for me) for most of their interactions and I am not proficient in the language, so a language barrier existed which hindered the assessment of students through one-on-one interaction. Also sometimes the videos that had to be shown were not available in vernacular languages the students did not find those videos to be engaging. That led to breaks in the line of inquiry which had to be filled with scaffolding which results in the inefficient implementation of the model.
2. The lab of the school was ill-equipped, so lesser activities and demonstrations could be implemented than were planned. The activities were simple enough, but even basic stuff like clinical thermometer was not available. This serious shortage of resources led to resorting to less experimental and more visual methods of learning for sparking the inquiry during different phases of the inquiry.

   The individual sessions were 40 mins long but often time ran out before we could reach a fruitful end for the day. This led to uncalled for pauses in the inquiry. Time is a major constraint which needs to be accounted for before planning any inquiry course however the structure has to be flexible enough to allow time when needed because inquiry cannot be rushed

3.8 Future Prospects:

1) Studying the curriculum development and methodologies to make it more responsive and flexible to the needs of the learner.
2) The proper assessment has to be designed to test the success of not only students but also of the program.
3) Long term effects of IBSE have not been studied which makes it a possible topic for further research.
4) I am designing a database of proper inquiry questions and other relevant inquiry conducting tutorials to ensure that teachers have good references for designing their inquiry so that inquiry leads to some fruitful conclusion.
5) Taking into consideration the different psychologies of children and studying how they learn best before designing pedagogical strategies.

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Appendices

Appendix 1

Test 1 questions

1. What is the difference between heat and temperature?
2. Which feels warmer- One thick coat or two thinner coats?
3. If you want to heat water quickly, should you coat the vessel black or white?
4. If you want to keep the water hot, should you coat the container black or white?
5. A cup of hot tea is placed on a table. What is the mode of heat transfer?
6. What is the final temperature of the mixture- water at 40 degrees added to milk at 40 degrees?
7. How is the weather in plains different from than in the coastal areas?
8. How does the sun’s heat reach us?
9. Which day will be colder- with fog or without fog? Why?

Appendix 2

Test 2 questions

1. What is the final temperature of the mixture- water at -10 degrees added to water at 20 degrees?
2. What is the direction of wind at night in coastal areas?
3. Which is at higher temperature when placed in sun- water or sand?
4. Why do buffaloes sit in water during summers but not cows?
5. Why is the cooler's handle made of plastic?
6. If a clinical thermometer is placed in water at 50 degrees, what temperature will it show?
7. How is an animal living in the mountains different from the animal living in plains and how do they survive?
8. How does a hot cup of tea lose temperature in air?
9. How does a hot cut of tea lose temperature when placed in a bowl of water?
10. Why does water from hand-pump feel so cold in summer and warm in winters?

Appendix 3

Common misconceptions leading to pedagogical malpractices (building a glossary)

- The traditional (mainstream) education system seldom differentiates between information and knowledge, problem-solving and scientific aptitude. A brief discussion of the terms will bring out their differences as well as the need to treat them differently.
    a) Information: Facts obtained after refinement of raw data, presented systematically in a given context constitute information. It can be gathered from newspapers, internet, people, books, etc.
    b) Knowledge: The theoretical/practical familiarity of an entity and the ability to use for a particular purpose refers to knowledge. It might be gathered through experience, intuition, perceiving, discovering, analysis etc.
    c) Problem-solving: The ability to visualize and filter relevant data out of a given set of facts and then being able to apply some set of rules to come up with a solution to the problem. It may be natural in some individuals but can be learned through proper training and guidance.
    d) Aptitude: The innate potential of a person's mental faculties which may enable him/her to apply that intellectual capacity to learn a specific discipline will be a measure of their aptitude towards that specific field of study. For example, an individual is said to have a scientific aptitude if their cognitive abilities allow them to visualize and perceive abstract things, be good at reasoning with numbers and language, analyzing patterns and other similar cognitive requirements needed to learn science.
- The terms inquiry learning and learning inquiry skills are different and need to be understood properly about each other.
    a) Inquiry learning: It is the process of learning through self/group conducted investigations and finding answers to posed questions through those investigations, which may or may not be facilitated by a guide.
    b) Inquiry skills: In the process of learning through inquiry, the learner needs some prior skills to conduct the relevant investigation. Those skills might include data recording, statistical analysis, equipment knowledge, etc. These are the inquiry skills which enable learning through inquiry.
- The terms course objective, learning goals and learning outcomes:

a) Learning goals: It is a general definition of the competence of the student in various areas they need to be educated in. Those areas might be critical questioning and logical reasoning, the ability to connect knowledge from two or more seemingly different disciplines, conflict resolution, etc.
b) Course objectives: It is a general idea about the topics the instructor will cover over the term. It's lesser broad than goals but encompasses learning outcomes.
c) Learning outcomes: It is a detailed description of what a student must be capable of after the course and what will be the acceptable performance level.