Developing Mathematics Laboratory – A Shift from Narrow Goals towards Higher Goals for Quality Elementary Education in Mathematics

Minara Yeasmin
Assistant Professor, Department of Education, Aliah University, Kolkata, West Bengal, India

Abstract: Mathematics in all consequence relates to real life and the applications of its concepts in our daily activities make life easier and interesting. Mathematics is the foundation for success in a variety of content areas during a child’s educational experience. Since RTE 2009 assures quality elementary education to every child, mathematics laboratory may prove to be one of the important step to improve achievements in mathematics. Again, the learning style of children is not same universally. Hence, this paper explicitly discusses the concept of mathematics, mathematics laboratory and its importance, and how to set a mathematics laboratory for quality elementary mathematics education. National and international journals, government documents, doctoral theses, and research articles have been used as secondary source of information. It recommended that adequate training through workshops be given to mathematics teachers on the effective use of standard laboratory in the teaching and learning of mathematics.

Keywords: Elementary Education, Mathematics, Quality Education, Quality Mathematics Education, Mathematics Laboratory, Aims of Mathematics Teaching and Learning

1. Introduction

Mathematics, according to National Education Policy 1986, should be visualised as the vehicle to train a child to think, reason, analyse and articulate logically. Apart from being a specific subject, it should be treated as a concomitant to any subject involving analysis and reasoning. With the introduction of computers in schools, educational computing and emergence of learning through understanding of cause-effect relationships and the interplay of variables, the teaching of mathematics will be suitably redesigned to bring it in line with modern technological devices so that learning takes place effectively. Learning often takes place best, when students have opportunities to express ideas and get feedback from their peers. Feedback, to be most helpful to learners, must consist of more than the provision of correct answers. It ought to be analytical, to be suggestive, and to come at a time when students are interested in it. And then there must be time for students to reflect on the feedback they receive, to make adjustments and to try again - a requirement of Mathematics education that was neglected due to rigorous use of traditional methods of teaching. The traditional methods of teaching are no longer adequate to meet the demands of modern mathematics education. In order to develop the skills reiterated in the policy and to provide practical experience of mathematical concepts, assumptions, assertions and rules, a strategy for teaching mathematics and a suitable platform to use such strategy is the need of hour. Every student has a unique way of thinking, learning and making sense of what s/he listens or observes. His/her active imagination constantly builds new connections. It assimilates new information. If the teacher is active speaker, the learning takes backseat and in the process, some faulty ideas can also form and lead to several learning gaps. These learning gaps need to be identified, questioned and corrected before they result into misconceptions. These misconceptions lead to low self-efficacy among students resulting low performance in the subject of mathematics. Learner learns faster, when he/ she is influenced by his/her peer group. The role of teacher is reduced to facilitator. However to reduce the role of a teacher to facilitator, a change in methods of teaching is inevitably seen. A strategy for teaching mathematics in a mathematics laboratory atmosphere that would transform the position of the teacher from being active speaker to facilitator of learning is the need of the hour. Hence this study was taken up.

2. Elementary Education

Elementary Education in India means the education from first class to eighth class. As elementary education is the base of the educational pyramid, it is here that the country must ensure access to good quality education for all the sections of the population with special attention to the needs of the SC, ST, OBC and minority communities and girls.
The 86th Constitutional Amendment Act, 2002 led to a new Article 21-A in Part III of the Constitution that made Free and Compulsory Education to all children of 6 to 14 years of age, a Fundamental Right. It is imperative to give good quality elementary education to all children in the age group of 6 to 14 years. The Right of Children to Free and Compulsory Education (RTE) Act, 2009, became operative on 1 April 2010. According to Right to Free and Compulsory Education Act, 2009:

1. Every child of the age six to fourteen years shall have the right to free and compulsory education in a neighbourhood school till completion of elementary education.
2. Where child above six years of age has not been admitted in any school or though admitted could not complete his or her elementary education, then he or she shall be admitted in a class appropriate to his or her age.

It provided further that a child so admitted to elementary education shall be entitled to free education till completion of elementary education even after fourteen years.

Regarding curriculum and completion of elementary education the Act stated that the curriculum and the evaluation procedure of elementary education shall be laid down by an academic authority to be specified by the appropriate Government, by notification. The academic authority while laying down the curriculum and the evaluation procedure shall take into consideration the following, namely –

(a) Conformity with the values enshrined in the constitution
(b) All round development of the child © Building up child’s knowledge
(d) Development of physical and mental abilities to the fullest extent.
(e) Learning through activities, discovery and exploration in a child friendly and child centred manner.
(f) Medium of institution shall, as far as practicable be in child’s mother tongue .
(g) Making the child free of fear, trauma and anxiety and helping the child to express views freely.
(h) Comprehensive and continuous evaluation of child’s understanding of knowledge and his or her ability to apply the same.

Further, stated that no child shall be required to pass any Board Examination till completion of elementary education. Every child completing his elementary education shall be awarded a certificate, in such form and in such manner, as may be prescribed.

Mathematics is the foundation of science and technology and the functional role of mathematics to science and technology is multifaceted and multifarious that no area of science, technology and business enterprise escapes its application (Okereke, 2006). Ukeje (1986) described mathematics as the mirror of civilization in all the centuries of painstaking calculation, and the most basic discipline for any person who would be truly educated in any science and in many other endeavours.

3. Importance of Mathematics In Elementary Education

The spirit of modernity and development in nations is reflected in their investment in children’s education in general. If science education is often termed as societal investment in the envisioned future, education in the “high roads of mathematics” perhaps constitutes their hope for the as-yet dream of future.

Right from human existence on this earth, the man wanted to answer the questions like; How many? How much? How big? How long? etc. For answering these questions man invented arithmetic, algebra, geometry. This knowledge was born in the need of human.

There is need of Mathematics in anybody’s day-to-day and lifelong planning, evaluation, assessment, judgment, guidance and direction for future. The prices, rates, discounts, commissions, rebates, interest, taxes, production, distribution, profit, loss, bank, post, shares trading etc. are the issues concerned to everybody. There is no escape from Mathematical concepts of life and livelihood. If we shut off Mathematics from daily life and all civilization comes to a standstill. Human being needs minimum knowledge of Mathematics for their survival. It is need daily by everybody consciously or unconsciously out of his /her necessity. Any person unaware of Mathematics will be easily cheated. Mathematics has a continual power on our everyday lives, and makes a payment to the wealth of the country. Thus knowledge of Mathematics fundamental processes in Mathematics and the skill to use them are the initial requirements of a human being these days.

The landscape of mathematics education in India calls for a very broad vision to encompass and comprehend. It is not only a matter of scale and magnitude in numbers of children and teachers that constitute the system, but also messy but democratic modes of functioning in which there are pulls from many social and political aspirants of society. We want every child to learn mathematics and enjoy it; the reality of achieving this with
millions of children and teachers by democratic means provides a major systemic challenge. Before we look at how this affects mathematics education specifically, we need an understanding of the vast system it operates in. The law called Right of Children to Free and Compulsory Education Act (abbreviated as Right to Education or RTE Act) came into force in India as recently as April 1, 2010. It guarantees 8 years of elementary education to every child in the age group 6-14 in an age appropriate classroom in the vicinity of his/her neighbourhood. This implies the right of every Indian child to quality mathematics education as well.

As elementary education is the base of the educational pyramid, it is here that we must ensure access to good quality education for all the sections of the population with special attention to the needs of the SC, ST, OBC and minority communities and girls. The 86th Constitutional Amendment Act, 2002 led to a new Article 21-A in Part III of the Constitution that made Free and Compulsory Education to all children of 6 to 14 years of age, a Fundamental Right. It is imperative to give good quality elementary education to all children in the age group of 6 to 14 years.

4. Significance of the Study

Elementary education forms the basis of mental development in a child, and equips him/her with the analytical skills, confidence and competencies which help pave the way for a successful future for him/her. Hence, it is imperative for nations to focus their attention on providing quality elementary education to their citizens, especially to the underprivileged sections of the society and empower the masses with a quality education that can enable them to break the shackles of poverty.

The main reason for studying mathematics is that it is interesting and enjoyable. People like its challenge, its clarity, and the fact that you know when you are right. Sidhu, Kulbir Singh (1985) explained the importance of Mathematics and it is helpful to Mathematics, according to National Education Policy 1986, should be visualized as the vehicle to train a child to think, reason, analyse and articulate logically. Apart from being a specific subject, it should be treated as a concomitant to any subject involving analysis and reasoning. Despite the importance placed on mathematics, researchers (Odili, 1986; Salau, 1995; Amazigo, 2000; Agwagah, 2001; Betiku, 2001; Obioma, 2005; Maduabum and Odili, 2006; Okereke, 2006) had observed that students lack interest in the subject and perform poorly in it. Ukeje (1986) observed that mathematics is one of the most poorly taught, widely hated and abysmally under-stood subject in secondary school, students particularly girls run away from the subject. The study of mathematics has been and will continue to be of tremendous importance to humanity for its ability to explain natural phenomena and everyday occurrences as well as its central role in the world’s technological development. Rahman and Amoo (2004) have noted that the importance of mathematics does not only lie in its development but also in its utility in day to day interactions. Ogunkunle (2007) noted that the widespread utility of mathematics in scientific and technological applications has made mathematics education a key predictor of scientific competitiveness. Moore (2005) asserted that mathematics is the logical language for expressing ideas, shapes, quantities, sizes, order, change and dynamism in the system, and for explaining the complexities of modern society in the business, economic, academic, engineering and medical settings. Mathematics comprises number and numeralation, algebra, trigonometric, geometry, mensuration, statistics and probability. Kolawale and Oluwatayo (2004) stated that the knowledge of mathematical concepts with the corresponding knowledge of their application to real life seems to be deteriorating.

Modern technologies have changed the way the subjects are taught. Learning these days takes place with students getting opportunities to express their ideas, they need to be actively involved in the process of teaching learning and efforts to give hands on experiences must increase because it is finally the active learning that stays with the children forever. In order to facilitate learning it is necessary to create opportunities where there is a possibility of getting immediate feedback from teachers and peers. Any laboratory for that matter creates such opportunities, and mathematics lab is no exception to this. In a regular classroom, students don’t get time to reflect they just listen and mug up with understanding causal relationships. That is the reason why the higher order skills of analysis, synthesis don’t get developed in them. Sometimes this even leads to hatred towards mathematics. It is felt that Mathematics laboratory would build right attitudes towards the subject and give long term benefits to the learners. Let’s try to understand what is mathematics lab? When thinking of Mathematics Laboratory, one really imagines big charts, calculators tablet PCs, puzzle books, toys based on mathematical logic, various geometrical shapes, blocks etc. Guidelines given by C.B.S.E. defines Mathematics laboratory as, “a place where students can learn and explore mathematical concepts and verify mathematical facts and theorems through a variety of activities using different materials.” These activities may be carried out by the teacher or the students to explore,
to learn, to stimulate interest and develop favourable attitude towards mathematics. Concept of Mathematics Laboratory introduced by the CBSE Board (Circular No. 03/28.01.04) aims to remove the fear for Mathematics among children and to make the subject more interesting and All affiliated schools were advised to start the Mathematics Laboratory for classes III onwards and integrate evaluation of practical competencies in Math with the evaluation of the subject.

Access to quality mathematics education is every child’s right. On the other hand, mathematics education in schools is based with problems. Due to hierarchy of concepts & largely deductive & abstract nature of the subject mathematics is considered as a very difficult subject. Taking into consideration the national aspirations & expectations reflected in the recommendations of the national curriculum framework developed by NCERT many educational boards & educational bodies have been initiating number of steps to make teaching & learning of mathematics activity based & experimental oriented.

The traditional didactic methods of teaching are no longer adequate to meet the demands of mathematics education in line with National Education Policy 1986. In the light of National Education Policy 1986, to develop the skills reiterated in the policy and to provide practical experience of mathematical concepts, assumptions, assertions and rules, an appropriate method of instruction or a strategy for teaching mathematics and a suitable platform to use such strategy is the need of hour.

In fact, from many years ago, some renowned mathematician and psychologist had gave their opinion in favour of mathematics laboratory for teaching and learning mathematics. But we are still deliberating on that matter. Here some of their foundation / principles are highlighted.

"The nature of mathematics is independent of us personally and of the world outside."

(Jourdain)

Mathematics in its purest sense is an abstraction. Whether it was discovered by or has been created by mankind is perhaps a philosophical point and need not concern us here; but the fact is that it exists, and it is extremely useful in describing and predicting events in the world around us. How then is it so useful if it exists “independent of us personally and of the world outside?” The answer lies in the ability of mathematics to model effectively numerous aspects of the real world. It does this by creating abstract structures that have properties or attributes similar to its real-world counterpart. If the model behaves in a manner that truly parallels the original, then it becomes possible to manipulate and use the model to make conclusions and/or predictions about its counterpart in the real world. We can do this because we know the two systems "behave" in the same manner and because we know that an operation in one system will have its counterpart in the other.

"Perhaps the most important single proposition that the educator can derive from Piaget's work, and its use in the classroom, is that children, especially young ones, learn best from concrete activities" (Ginsberg and Oppen 1969, p. 221). This proposition, if followed to its logical conclusion, would substantially alter the role of the teacher from expositor to one of facilitator, that is, one who promotes and guides children's manipulation of and interaction with various aspects of their environment.

Unlike Piaget, Dienes has concerned himself exclusively with mathematics learning; yet like Piaget, his major message is concerned with providing a justification for active student involvement in the learning process. Such involvement routinely involves the use of a vast amount of concrete material.

Any idea or a concept presented in a simple & appropriate form and the way that is suitable to learner's ability and aptitude provides the best of understanding of it (Bruner 1966). Mathematics is a science. As like other science subjects, Mathematics also provides activities. It is helpful to pupils to develop the interest and confidence in learning.

The results of this study will be useful to develop a Mathematics laboratory (as per NCERT curriculum framework 2001). Mathematics laboratory existed in only 19% of the schools. Overall, only 31% of the teachers attended a training programme based on NCF-2005.(NCERT.NAS,CYCLE 3, 2014).Every student has a unique way of thinking, learning and making sense of what he/she listens or observes. Their active imagination constantly builds new connections and assimilates new information. If the teacher is active speaker and persistently using traditional methods, the learning takes backseat and in the process some faulty ideas can also form and lead to several learning gaps. These learning gaps need to be identified, questioned and corrected before they result into misconceptions. These misconceptions lead to low self- efficacy among students resulting low
performance in the subject of mathematics. Learner learns faster, when he is influenced by his peer group and developing a sense of positive interdependence, besides reducing the role of teacher to facilitator. However, reducing the role of a teacher to facilitator and creating an atmosphere of positive interdependence among students, a change in methods of teaching is inevitable requirement. In a normal course of teaching mathematics in a classroom, creating such atmosphere as mentioned above is not possible.

So, a strategy for teaching mathematics in a different but suitable atmosphere that would transform the position of the teacher to facilitator of learning from an authoritarian and active speaker’s role was the need of the hour. Hence this study was taken up. In this context we can add the recommendations on Proposed New Education Policy 2016 by National Commission for Protection of Child Rights (NCPCR): “Enrich classrooms at both pre-primary and primary level with a wide range of local collections (such as seeds, leaves, etc.), tools (such as lens, magnet, scientific toys, etc.), charts, posters, colourful encyclopaedias and reference books to practice science and share experience. Keep the science kits, mathematics kits and other learning materials in the reach of children so that they learn how to use those, clean, keep back and maintain……. Quality of all government schools should be upgraded like Kendriya Vidyalyas, Navodya Vidyalyas. Focus should be on quality education”

Therefore, to raise the voices for developing mathematics laboratory is very much related to the quality of elementary mathematics education and for that reason the author has selected such relevant topic.

5. Objectives of the study

Specifically, this paper aims at
1. Defining mathematics and a mathematics laboratory
2. Emphasizing of quality mathematics in elementary education (specifically for the classes VI-VIII).
3. Listing and identifying mathematical equipment/materials that can be put in a mathematics laboratory for elementary education and
4. enumerating ways of setting mathematics laboratory in the school. Listing some useful activities and projects suitable for elementary mathematics education. To this end, this paper focuses on setting mathematics laboratory which directly houses instructional materials.

6. Mathematics

Mathematics according to (Nwoke & Nnaji, 2011) is the study of quantity, structures, space and change. It developed through the use of abstraction and logical reasoning from counting, calculation, measurement, and the study of the shapes and motion of physical objects. The ingredient for the effective articulation of the abstract elements of science that gives drive to the development of technologies of any nation is based on mathematics. The indispensability of mathematics is in human day to day activities cannot be over emphasized; therefore considered as the bedrock of all scientific and technological breakthrough and advancement for all the activities of human development. It is the language and culture common to all studies (Harbor-Peters, 2000). In the following some more definition are set together.

1. The abstract science which investigates deductively the conclusions implicit in the elementary conceptions of spatial and numerical relations, and which includes as its main divisions geometry, arithmetic, and algebra. (Oxford English Dictionary: 1933).

2. The study of the measurement, properties, and relationships of quantities and sets, using numbers and symbols. (American Heritage Dictionary:2000)

3. Mathematics is the science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. (Encyclopaedia Britannica:2010).

4. Mathematics involves thinking logically and reasonably so as to understand how formulae are derived and their applications. In order to enhance learners’ mastery and meaningful learning of mathematics, it is necessary to reduce to the bearable minimum its level of abstraction with the use of instructional materials. Adenegan (2010) testified to this that instructional materials, when properly used in the teaching and learning situation, can supply concrete bases for conceptual thinking, high degree of interest for students in making learning more permanent. According to Oyekan (2000), “instructional materials are those things that can facilitate effective teaching and pleasant learning that is teaching aids through which learning process may be encouraged and
motivated under the classroom situation”. These enhance the teaching learning process when adequately and appropriately used.

5. Mathematics is a way of organizing our experience of the world. It enriches our understanding and enables us to communicate and make sense of our experiences. It also gives us enjoyment. By doing mathematics we can solve a range of practical tasks and real-life problems. We use it in many areas of our lives. In mathematics we use ordinary language and the special language of mathematics. We need to teach students to use both these languages. We can work on problems within mathematics and we can work on problems that use mathematics as a tool, like problems in science and geography. Mathematics can describe and explain but it can also predict what might happen. That is why mathematics is important.

7. Aims of Teaching Of Mathematics

Education is imparted for achieving certain ends and goals. Various subjects of the school curriculum are different means to achieve these goals so with each subject some goals are attached which are to be achieved through teaching of that subject.

Mathematics education are to enable students to:
(i) Acquire the necessary Mathematical concepts and skills for everyday life, and for continuous learning in Mathematics and related disciplines.
(ii) Develop the necessary process skills for the acquisition and application of Mathematical concepts and skills.
(iii) Develop the Mathematical thinking and problem solving skills and apply these skills to formulate and solve problems.
(iv) Produce imaginative and creative work arising from Mathematical ideas and develop positive attitudes towards Mathematics.

According to NCF-2005, the main goal of mathematics education in schools is the mathematization of the child’s thought processes. There are two aims of school mathematics – the narrow aim and higher aim.

The narrow aim of school mathematics is to develop ‘useful’ capabilities, particularly those relating to numeracy-numbers, number operations, measurements, decimal and percentage. The higher aim is to develop the child’s resources to think and reason mathematically, to pursue assumptions to their logical conclusions and to handle abstractions. These aims could be achieved through the use of innovative Mathematics teaching strategies instead of the conventional approach.

8. The Quality Dimension

According to some Indian academic the central challenge of Indian education is dealing with the metaphorical triangle of quantity, quality and equality. The state sector in education is plagued by major shortage and uneven spread of resources, as witnessed by the large percentage of single classroom schools. Such extreme shortage of resources presents a tremendous quality constraint. Much worse, and especially relevant to mathematics education, is lack of qualified and committed teachers. No system can rise above the quality of its teachers, and content knowledge of mathematics is vital for mathematics education. Indian society is division-riven and this provides a great challenge for quality and equality in education. Mathematics being a compulsory subject of study, access to quality mathematics education is every child’s right. On the other hand, there is considerable research to suggest that teacher preconceptions, bias and behaviour, causes discrimination against children from the groups with low socio-economic status, the so-called “Scheduled Castes” (SC) and “Scheduled Tribes” (ST). Also the girls who do come to school are subject to social discrimination as well. In rural areas preconceptions such as mathematics being “unnecessary” for girls can be observed even among teachers. Despite the better performance of girls in Board examinations than boys in recent years, the stereotype that boys are better at mathematics than girls is seen to persist. The social context of Indian education is reflected in the sharp disparities between different social and economic groups, which are seen in school enrolment and completion rates. Thus, girls belonging to SC and ST communities among the rural and urban poor and the disadvantaged sections of religious and other ethnic minorities are educationally most vulnerable, and data confirm this. Quality in education is inherently dependent on the following six aspects: (i) curriculum and learning objectives, (ii) learning materials, (iii) pedagogic processes, (iv) classroom assessment frameworks, (v) teacher support in the classrooms, and (vi) school leadership and management development. A new framework for curriculum is needed at regular intervals in order to take cognizance of the developing issues in society and how to address them. As education is concerned with all-round development of the child (physical, socio-emotional along with cognitive), all aspects need to be assessed rather than only academic achievement. During the Twelfth Plan, however, there will be a system-wide focus on holistic development of children by improving learning outcomes and other non-scholastic areas. Learning
enhancement programme (LEP) under the SSA would be continued in the Twelfth Plan, for which specific zones of operation should be identified by the concerned State/District authorities. Every year, States need to articulate the learning goals that are being targeted and the strategies (methods, materials, models and measurement) that will be used to reach those goals. Does our mathematics teaching in schools comply with these expectations? Students’ dismal performance was seen in mathematics examination conducted by NCERT through the National Learning Achievement in mathematics. In the year 2014 in the National Achievement Survey (NAS) for class VIII in mathematics conducted by NCERT the average score of 33 states/ UTs was 245 out of 500 with SE of 0.6. Also the mean value of result (out of 100) in mathematics found by them in the year 2012 is given below:

Table 1: Mean value of result in mathematics (out of 100) in 2012

<table>
<thead>
<tr>
<th>Round</th>
<th>Grade III</th>
<th>Grade V</th>
<th>Grade VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round I</td>
<td>58.25</td>
<td>47.45</td>
<td>39.17</td>
</tr>
<tr>
<td>Round II</td>
<td>61.88</td>
<td>49.88</td>
<td>42.17</td>
</tr>
</tbody>
</table>

In the report “Assessing the Impact of Right to Education Act”, done by Klynveld Peat Marwick Goerdeler KPMG with collaboration of CII (Confederation of Indian Industry) in March 2016 it is mentioned that about 19.5% of all the studied children in class two were not able to recognize number upto nine, close to 74% of all the studied children in class three could not do two digit subtraction and close to 74% of all the studied children in class five were not able to do division.

9. What is a Mathematics Laboratory?

Mathematics Laboratory is a place where students can learn and explore mathematical concepts and verify mathematical facts and theorems through a variety of activities using different materials. These activities may be carried out by the teacher or the students to explore, to learn, to stimulate interest and develop favourable attitude towards mathematics. That is, a mathematics laboratory is a place where we find a collection of games, puzzles, teaching aids and other materials for carrying out activities. These are meant to be used both by the student by their own and together with their teacher to explore the world of mathematics, to discover, to learn and to develop an interest in mathematics. Although mathematics is not an experimental science in the way in which physics, chemistry and biology are, a mathematics laboratory can contribute greatly to the learning of mathematical concepts and skills.

10. Mathematics Laboratory – What does Research Say?

Mathematics laboratory is a place where students can explore mathematical objects, shapes and symbols to learn and verify mathematical facts and theorems through a variety of activities using different materials. These activities may be carried out by both the teachers and the students to explore, learn, stimulate interest and develop favourable attitude forwards mathematics (Sreedharal, 2008). Olatunde (2010) studies the adequacy of resource materials (Mathematics laboratory) and students mathematics achievement of senior secondary schools in south western, Nigeria. The study revealed that out of 1750 senior secondary school students and 123 mathematics teachers selected from 2 schools of the senatorial districts (75%) have a, good perception about the need for mathematics laboratory and students exposed to use of mathematical laboratory performed better (65%) than those who were not exposed to it. The use of Mathematics Laboratory as a Pedagogical approach in teaching and identifying students’ difficulties in mathematics has been effective. Nwoke and Nnaji (2011) showed that the use of Mathematics Laboratory was more effective than the lecture method in teaching and learning mathematics with respect to students’ achievement. Similarly, Sidhu (2006), considered mathematical laboratory as a place where things can be stored, kept, counted, ordered, recorded, packaged, unpackaged, grouped, ungrouped, arranged, rearranged, mantle and dismantle, measured, joined, portioned, among numerous other activities. Sreedharal (2008) supported this advocacy by positing that the activities carried out in the mathematics laboratory make students enjoy and rejoice with mathematics. Mathematics Laboratory is further seen to enhance students’ ability to carry out their projects and other activities which provide active sensory mathematical experiences (Ukpebor, 2011). Hence, mathematics laboratory should be a focal point of all mathematics work in schools. Ogunkunle (2007) opined that secondary school teachers use conventional methods in teaching mathematics concept and this method does not impact positively on academic achievement of students in mensuration which requires mastering of concepts before computation. The teaching and learning of mathematics concepts should be by
practical, exploration and experiment, using a mathematics laboratory. This will make students organize their true potentials, talents, cultivate habits of hard work, high moral, ethical standards to learning mathematics and description of its value system to real life situations and national economic growth. In mathematics laboratory, abstract concepts should be demonstrated using concrete materials. This is capable of enhancing students’ interest in mathematics (Onwuka, Moseri and Iweka, 2010). Furthermore, by hierarchical nature of mathematics, the knowledge gained at any level using the laboratory materials could improve students’ performance. In mensuration a bit concerns measuring, calculating and estimating length, areas and volumes as well as the construction of three dimensional objects, it requires laboratory based activities. Using improvised materials to teach concepts in mathematics especially in mensuration could go a long way to accomplish the expectations of all to bring about enhanced achievement. Mohammed & Kurumah (2012) carried out research work on the use of montessori approach (Mathematics laboratory approach) in promoting students’ interest in mensuration. The result of this study showed gender as statistically significant in which the male students performed better than the female students (F=10.248, p < 0.05). Although, in the view of Obarakpo(2009), in determining the effect of active learning in students’ achievement in mensuration, the male students did not perform significantly better than the female students. Mathematics is an excellent vehicle for the development and improvement of a person’s intellectual competence in logical reasoning, spatial visualization, analysis and abstract thought (Curriculum Planning and Development Division, Africa, 2007). Students who study Mathematics, therefore, develop numeracy skill, reasoning, thinking skills and problem solving skills through the learning and application of Mathematics.

11. Need and Purpose of Mathematics Laboratory

Some of the ways in which a Mathematics Laboratory can contribute to the learning of the subject are:

- It helps the students to build interest and confidence in learning the subject.
- The laboratory provides opportunity to exhibit the relatedness of mathematical concepts with everyday life.
- It gives more scope for individual participation. It encourages students to become autonomous learners and allows a student to learn at his or her own space.
- It provides scope for greater involvement of both the mind and the hand which facilitates cognition.
- The laboratory allows and encourages the students to think, discuss with each other and the teacher and assimilate the concepts in a more effective manner.
- It enables the teacher to demonstrate, explain and reinforce abstract mathematical ideas by using concrete objects, models, charts, graphs, pictures, posters, etc.
- It widens the experiential base, and prepares the ground for later learning of new areas in mathematics and of making appropriate connections.
- In various puzzles and games, the students learn the use of rules and constraints and have an opportunity to change rules and constraints. In this process they become aware of the role that rules and constraints play in mathematical problems.
- Because of the larger time available individually to the student and opportunity to repeat an activity several times, students can revise and rethink the problem and solution. This helps to develop meta cognitive abilities.
- It builds up interest and confidence in the students in learning and doing mathematics.
- Importantly, it allows variety in school mathematics learning.
- Mathematics Lab provides a conducive ambience for students to learn the subject in a joyful manner through practical activities and interaction.
- Teachers need to pay attention to both the transactional strategies and evaluation strategies.
- Simple experiments and projects will lead to the development of different skills like numerical, observation, thinking, analytical and so on.
- Establishing a Mathematics Lab does not involve high cost. Improvised aids using inexpensive material can be made.
Space required is also quite limited.

12. Design and General Layout

A laboratory is equipped with instruments, apparatus, equipments and models apart from facilities like water, electricity etc. Non availability of a single material or facility out of these may hinder the performance of any experiment/activity in the laboratory. Therefore the laboratory must be well managed and well maintained.

The design is only a suggestion. The schools may change the design and general layout to suit their own requirements.

12.1. Physical Infrastructure And Materials

It is envisaged that every school will have a Mathematics Laboratory with a general design and layout as indicated with suitable change, if desired, to meet its own requirements. The minimum materials required to be kept in the laboratory may include furniture, all essential equipment, raw materials and other necessary things to carry out the activities included in the document effectively. The quantity of different materials may vary from one school to another depending upon the size of the group.

12.2. Human Resources

It is desirable that a person with minimum qualification of graduation (with mathematics as one of the subjects) and professional qualification of Bachelor in Education be made incharge of the Mathematics Laboratory. He/she is expected to have special skills and interest to carry out practical work in the subject. The concerned mathematics teacher will accompany the class to the laboratory and the two will jointly conduct the desired activities. A laboratory attendant or laboratory assistant with suitable qualification and desired knowledge in the subject can be an added advantage.

The activities could be done individually by students, with guidance from a teacher, or could be used for demonstration with a small group of students. Some of the activities could also be used as teaching aids in a classroom. The games and puzzles are fun to do individually and all of them contain some element of mathematics which can be explored while doing them or as a sequel.

12.3. Time Allocation for activities

It is desirable that about 15% - 20% of the total available time for mathematics be devoted to activities. Proper allocation of periods for laboratory activities may be made in the time table. The total available time may be divided judiciously between theory classes and practical work. In laboratory the students don’t just listen to the information given but do something practically also. Principles have to be discovered, generalized and established by the students in this method.

Students learn through hands on experience. This method leads the student to discover mathematical facts. After discovering something by own efforts, the student starts taking pride in his achievement, it gives him happiness, mental satisfaction and encourages him towards further achievement.

12.4. List of methods and materials used in the Mathematics laboratory

i. Paper folding
ii. Collage (Paper cutting & pasting)
iii. Unit Cubes (wooden or any material)
iv. Geo-board, rubber band
v. Transparency sheets, cello tape
vi. Graph paper
vii. Pins & threads
viii. Broom sticks
ix. Chart papers, glazed papers, sketch pens.
x. Stationery

12.5. List of activities

1A. To carry out the following paper folding activities:
Finding – Geometry
1. The midpoint of a line segment,
2. The perpendicular bisector of a line segment,
3. The bisector of an angle,
4. The perpendicular to a line from a point given outside it,
5. The perpendicular to a line at a point given on the line,
6. The median of a triangle.
7. To obtain a parallelogram by paper-folding.
9. To verify the midpoint theorem for a triangle, using paper cutting and pasting.
10. To divide a given strip of paper into a specified number of equal parts using a ruled graph paper.
11. To illustrate that the medians of a triangle concur at a point (called the centroid), which always lies inside the triangle.
1B. To carry out the following activities using a geoboard:

**Mensuration**
1. Find the area of any triangle.
2. Find the area of any polygon by completing the rectangles.
3. Obtain a square on a given line segment.
4. Given an area, obtain different polygons of the same area.
5. To show that the area of a parallelogram is product of its base and height, using paper cutting and pasting. (Ordinary parallelogram and slanted parallelogram)
6. To show that the area of a triangle is half the product of its base and height using paper cutting and pasting. (Acute, right and obtuse angled triangles)
7. To show that the area of a rhombus is half the product of its diagonals using paper cutting and pasting.
8. To show that the area of a trapezium is equal to half the product of its altitude and the sum of its parallel sides and its height, using paper cutting and pasting.

**Arithmetic**
1. Obtain length segments corresponding to square roots of natural numbers using graduated wooden sticks.

**Algebra**
2. To verify the identity \(a-b)^3 = (a-b)(a^2 + ab + b^2)\), for simple cases using a set of unit cubes.
3. To verify the identity \(a^3 + b^3 = (a + b)(a^2 - ab + b^2)\), for simple cases using a set of unit cubes.
4. To verify the identity \((a + b)^3 = a^3 + b^3 + 3ab(a + b)\), for simple cases using a set of unit cubes.
5. To verify the identity \((a-b)^3 = a^3 - b^3 - 3ab(a-b)\), for simple cases using a set of unit cubes.
6. To interpret geometrically the factors of a quadratic expression of the type \(x^2 + bx + c\), using square grids, strips and paper slips.
7. To obtain mirror images of figures with respect to a given line on a graph paper.

**Group Activities**
1. To find the percentage of students in a group of students who write faster with their left hand / right hand.
2. To help the students establish interesting mathematical relationships by measuring some parts of the body. (Height, Weight etc.)

12.6. Suggested list of Projects

P1. Observing interesting patterns in cricket match.  
Comparison of the performance of two teams in a one–day international football match.

P2. Design a crossword puzzle with mathematical terms  
To review mathematics vocabulary, to give the opportunity for creative expressions in designing puzzles, to act as a means of monitoring the study of a given unit and to give recreation.

P3 Cricket  
Collect data on runs scored in each over for a one–day international (ODI) cricket match and obtain frequency distribution between runs and overs. Do this for both the teams and also for the first 25 and the remaining overs of the match. Observe any interesting features of the match. Compare it with similar analysis for a few other ODI’s.

P4 Age profile in your neighbourhood  
Survey any 30 households in your locality and collect data on the age of the persons. Determine the age profile (number of persons Vs age) for men and women. Report any significant observation from the data.

P5 Educational Background in your neighbourhood  
Survey any 30 households in your locality and collect data on the educational background of the persons. Obtain significant observations from your data.

P6 Number of Children in a family in your neighbourhood  
Survey any 50 households in your locality and collect data on the number of children (male and female) in each family. Report any significant observation.

P7 Making of Platonic solids  
Obtain and construct the nets of five platonic solids. Make these solids and observe the properties (number of faces, edges and vertices) of the solids. Try to find out, why there are only five platonic solid. (Try taking regular hexagon)

P8 History of Mathematics  
Refer history of mathematics sources from your library or Internet and prepare a poster or a document on any topic of your interest. The students can choose several topics from history of mathematics, for doing a project. For instance the topic can be about an Indian mathematician or the
concept of zero, Pythagoras theorem, History of the number in various ancient civilizations.

**P9 Mathematics line designs**
Using strings obtain interesting designs and patterns. Use threads and shapes made by cardboard, try to make designs on it by making slits on the cardboard. Observe different patterns on it.

**P10 Computer project**
Using a spreadsheet programme on a PC obtain the graph of the equation ax + bx + c = 0 for a different values of a, b and c and note the interesting features and patterns. Interested students can also try for quadratic equations.
(Ref. CBSE: Guidelines for Mathematics Laboratory)

13. **Recommendations and Educational Implications**
The use of visualization tools, improved Mathematics laboratory apparatus and their utility should be established in both Primary and Secondary schools across the state. Also the persistence of teachers’ use of conventional teaching method in all content of Mathematics instruction should be discouraged through the teachers’ use of resource materials. Finally, workshops should be organized for Mathematics teachers on the use of Standard Laboratory apparatus in teaching Mathematics contents. The following recommendations were made based on the finding of the study:

- The teachers should use the strategy evolved for teaching mathematics in mathematics laboratory to enrich their teaching experiences.
- Mathematics laboratory should be made an integral part of curriculum of mathematics. Government should establish mathematics laboratory in all schools like other science subjects laboratories.
- Mathematics Teaching could be carried out in a Mathematics Laboratory by integrating mathematics laboratory into regular curriculum.
- A specific curriculum in the form of credits shall be prescribed as regular syllabi for Mathematics Laboratory and could be made it mandatory to students to complete.
- Process of Evaluation and Assessment shall be based on minimum number of mandatory credits by each student at each class could be made mandatory. Promotion to next class could be linked with this mandatory completion.
- Process of Evaluation and Assessment techniques shall be changed to a different format such as making rubrics for positive interdependence, group investigation skills etc., so that; academic performance of students could be improved along with social skills and peer interaction.
- Teaching through computers shall be introduced in the Basic teaching degree pursuit. All the pre-service teachers shall get ample exposure in using embedded atmosphere to teach mathematics.
- All In-service teachers shall be given training in Information & Communication Technologies, so that; the teaching experiences could be enriched. Pre-service teacher-students be given an exposure to Mathematics Laboratory and its usage in teaching mathematics. Techniques or strategies to integrate it ICT shall be taught during their teacher education programme. “Skilled and qualified teachers required to solve problems”- Recommendations on Proposed New Education Policy 2016 by National Commission for Protection of Child Rights (NCPCR).
- Mathematics student teachers should be trained on the use of mathematics laboratory in the mathematics methodology class.
- Addition human resources with mathematics background could be given for mathematics laboratory so as to enable the students to use the laboratory not only during their allotted periods, but also during leisure periods.
- In every school Mathematics Laboratory shall be established and teaching of mathematics shall be carried out through mathematics laboratory.

14. **Conclusion**
This study has an influence on the initiation of using mathematics laboratory in teaching of mathematics at elementary level. The ultimate result of the study revealed that mathematics laboratory appeared to be a befitting platform for creating positive interdependence as compared to classroom. The study suggested that; traditional didactic methods of teaching do not facilitate learning by understanding nor providing opportunities to students to relate their knowledge
with real life, besides making low performers in the
subject of mathematics. It was further established
that, use of strategy evolved integrating three
different methods for teaching mathematics in a
Lab atmosphere yielded improved performance of
students. Hence, teachers teaching mathematics
should use Mathematics Laboratory as a platform
and by using the strategy or any method other than
didactic methods to make a significant impact in
the knowledge construction so as to improve the
performance of students of elementary school.

- We need a new mindset, a new thought
process, a new paradigm of instructional
leadership that can boldly raise questions
such as

1) How long do we wait for quality
mathematics education at elementary
level?
2) How long do we differentiate between
so called reputed Private schools and
Government / Government – aided /
Government sponsored schools?
3) When would we be able to drive out the
differences of our attitudes towards
boys and girls, majority and minority ,
economically sound and backward
students, privileged and underprivileged
.physically healthy and challenged
students?
4) When would we be able to give
opportunities to joyful mathematics
learning at elementary level?
5) How do we strengthen our internal
assessment system?
6) What are the ways in which we can
strengthen practical laboratory work?

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