Paradigm Shift Towards Practical Oriented Teaching Of Mathematics

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Abstract

This paper is aimed at highlighting the need for practical oriented teaching of mathematics for better conceptual understanding and improved mathematical problem solving ability among students studying at the high school level. This paper also attempts to inquire upon the teacher's attitude, preparedness, the possibilities and the pros and cons of whether practical oriented teaching of mathematics is made possible. Gowers (2016) insists on the need to teach mathematics, as practically as a teacher can. In the process, a concept steadily unfolds creating better scope for understanding and problem solving among children. It has been accounted from the reviews and observations in the classroom context that the need to teach mathematics practically contributes in enhanced conceptual understanding and problem solving ability.

Keywords: Practical oriented teaching, Practical mathematics, Activity-based teaching, Mathematics laboratory, Constructivism, Realistic Mathematics Education (RME).

Introduction

Mathematics teaching is a gratifying experience, demanding strenuous efforts from the teacher, right from the conception of the content till taking it to the minds of the pupil. The process in between defines the endeavour of mathematics teaching process relating its effectiveness with teaching methods, models of teaching, involving the pupils in activity, drill and practice, assessing their performance, etc. Among the major goals of mathematics teaching, the most important is the development of pupils' understanding of the concepts thus, aiming to advance the systematic development of problem solving ability.

The development of these processes is dependent on the careful organisation of content, teaching methodology, transactional strategies, knowledge about information processing, etc. All of these play a pivotal role in determining the learning outcomes. Moreover, the outcomes in mathematics teaching are not determined by the teacher defined strategies alone. As the factors are varied, with regard to comprehension, and conceptual understanding, rationalisation and interpretation processes determine the learning ability of the students and their learning outcomes, which hold a significant role in the achievement of teaching learning objectives.

Need to teach mathematics practically

Mathematics helps us think in an analytical way, to look into a particular instance in a more specific, logical, rationalised and analysed manner. It requires better analytical and reasoning skills to look into the problem and to understand its intricate nature. Practical understanding of mathematical

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concepts helps us think analytically, where more reasoning is expected. It helps to view the problems in multiple perspectives and to approach the problem with a view to looking for practical solutions.

When mathematics is taught practically, associating it with objects, life oriented tasks and activities, experimental activities with relevant teaching aids / equipment and apparatus, it helps to look at the problem perspective in a more practical way, than just approaching it to only solve the problem theoretically, based on the rules and formulas. Clark (1997) insists that there is a shift of emphasis from teaching mathematics through conventional methods to experiential learning. This is based on the understanding of the procedures, which may be learned through practical or project work that make up a subject's content using discovery and inquiry methods of instruction.

Constructivism and Realistic Mathematics Education

The difficulty in mathematics learning is attributed to many factors, such as conceptual understanding, continuity in concept construction, application of related concepts, its nature of symbolism, abstraction and attributes related to approaching a problem, etc., NPE (1986) highlights that, "mathematics should be visualised as a vehicle to train a child to think, analyze and articulate logically." This statement insists on the need for teaching and learning of mathematics in a more lucid manner. Another important aspect is that it intends to highlight that the subject has to be visualised to achieve meaningful knowledge. This highlights the need and significance of why mathematics has to be taught practically.

In the teaching and learning of mathematics, constructivism emphasises that it is necessary to find a mathematical object to prove that it exists. Clements & Battista (2009) highlight that, "in the constructivism pedagogy the mathematical knowledge and skills are actively acquired by the students and not just passively received from the environment; mathematical knowledge is created by reflecting on their physical and mental actions; learning of mathematics is thought of as a process of adapting to and organizing ones quantitative world."

Practical oriented teaching of mathematics involves children actively participating in the learning process in many ways, and not merely the use of practical aids and activities. It concentrates on involving them to meaningfully interact, discuss and analyse the rationale of the problem, investigate the concepts involved in it and attempt to solve it by the application of possible ways and means. This involves the basic tenets of constructivism in the learning of mathematics that "Knowledge is constructed, not transmitted. Prior knowledge impacts the learning process. Initial understanding is local, not global. Building useful knowledge structures requires effortful and purposeful activity."

Another significant approach in associating the basis and objectives of practical mathematics is Realistic Mathematics Education (RME), which aims at changing mathematics learning into more fun and meaningful for students by introducing them to problems within contexts (Laurens et.al. 2018). The instructional aspects in realistic mathematical education mainly concentrates on improving the ability of students in learning mathematics based on activities, meaningfully interacting the concepts and relating it to contexts thus, aiming at improved understanding and the problem solving ability in mathematics. Further, the study highlights that the RME approach fosters motivation, self-confidence, problem solving skills and reasoning that improve cognitive achievement. RME refers to asking students questions that they can think of (Wijdeveld, 1980, as cited in Laurens et.al. 2018). It was then followed by students solving mathematics problems (Treffers, 1987, as cited in Laurens et.al. 2018).

Practical understanding of mathematics requires experimental knowledge, dimensional thinking and handling of practical equipment and objects. For example, the subject geometry requires practical and spatial understanding and applied positioning in a multidimensional perspective. Practical oriented teaching of mathematics involves teachers' commitment in analysing the probable and appropriate areas of the subject, which has scope for teaching practically. For example, a high school level rule-based algebraic problem may have the scope for teaching through induction or deduction, which may have less scope for practical application.

Practical oriented teaching of mathematics benefits the teaching learning process by:

- Understanding mathematical concepts related to spatial relationships, dimensions, formula constructs, inherent and lateral conceptual understanding through concrete experiences.
- Helping the slow learners and average learners in mathematics to understand the perspective of problems through activities that are part of practical oriented teaching.
- Developing visualisation, manipulation and tactile skills that enhance active participation and interaction among learners when compared with the classroom teaching learning of mathematics.
- Developing analytical ability in understanding mathematical concepts in parts. Swanson (1993) observed that the whole–part–whole-learning experience provides the learner with a complete understanding of the content at various levels of performance and allows for higher order development.
- Understanding as Hukum et.al. (2005) has explained that laboratory-based mathematics teaching can prove to be an important breakthrough in overcoming most of the instructional weaknesses in the present day mathematics instruction.
- Grasping that practical oriented perspectives of mathematics provide scope for individual awareness, opportunity to discover, identify difficulties in understanding the concepts and learn through activity.
- Providing an opportunity to demonstrate teaching and explain the concepts using concrete teaching aids.
- Imparting an everlasting learning experience where the concepts formed through practical activity will remain in the learner for a considerably longer period of time.Providing scope for students to create aids, based on their own understanding thus, creating a room for discovery and innovative skills.

The probable areas, which have the feasibility of teaching through practical methods or practical activities, can be sorted out by following which specific teaching learning material, lab equipment/apparatus, teaching aids have to be identified for each topic/area. Identified teaching may be applied to use it for teaching practically. Achieving practical oriented teaching of mathematics is a collective effort of both the teacher and the pupil where in the major objective is to understand the concepts better when the subject is taught practically.

Bhatt & Subramaniam (1985) have compiled a manual on 'activities for the school mathematics lab'. Throughout the volume it may be observed that the authors have painstakingly identified various math laboratory-based activities. They have clearly illustrated each activity with neat sketches and illustrated how the classified laboratory activities may be put to use to teach various other related concepts.

Essential aspects of practical oriented teaching of mathematics

The abstract concepts in mathematics should be visualised, simplified and organised into concrete forms, which when taught practically can be well received. For example, mathematical concepts pertaining

to mensuration at the high school level, such as finding out the area, curved surface area, total surface area, perimeter, volume, etc., all have much scope for teaching practically by using simple paper folding models and low cost teaching aids that are readily available for use by the teacher and the pupil.

The teacher's effort in taking up each concept to the level of application and bringing in a visualisation to make students understand the concept better than just presenting it theoretically is important in the teaching of mathematics. Practical oriented teaching of mathematics benefits students with better understanding, concept attainment, and content fluency through visual perception. It provides experience in the real world applications and enhances their ability to visualise and solve the problems based on improved conceptual understanding, and problem solving ability. Practical oriented teaching of mathematics develops an individual's:

a. Content knowledge through objectified concept formation
b. Thinking skills in coordinating multiple concepts through practical activities such as manipulation, measuring and organising
c. Abilities related to association and discrimination, logical and collaborative skills
d. Learning the concepts in a more play-way, participative and activity modes
e. Capacity to analyse and synthesise, visualise and interpret, generalise and apply
f. understanding the advantages of teaching mathematics practically will facilitate the institutions to set up mathematics laboratory.

Evolution of practical mathematics

Practical mathematics has always been in practice, with critical thinking, inquiry and discussions over the possibilities of application of mathematical knowledge. Practical mathematics is about how the mathematical concepts are perceived from the applicational perspective and relating the theoretical concepts with practical ones and applying it in practical situations. In the past, practical applications have motivated the development of mathematical theories. While pure mathematics emerged as a discipline, which concentrated on logic more than application, practical mathematics is more concerned about applicational perspectives (Boyer, 1991).

The evolution of practical mathematics may be observed when the inquiry of mathematical knowledge is aimed on the basis of empirical, concrete and experiential aspects. Ebrahim (2010) classified the seven periods of mathematical practice based on its characteristics as:

- Proto-Mathematics (from the mists of ancient time, through the archaeological evidence of c.30000 BCE, up to 2000 BCE): empirical, concrete and basic
- Ancient Mathematics (from 2000 BCE up to 800 BCE): empirical, number and figures abstracted, not axiomatic
- Classical Mathematics (from 800 BCE to 1500 CE): axiomatic geometry
- Mercantile Mathematics (from 1400 CE to 1500 CE): improvement in numeration, symbolic development, and symbolic shorthand arithmetic, sophisticated algebra and solution of equations
- Pre-Modern Mathematics (from 1500 CE to 1700 CE): functions, continuous mathematics, analytic geometry, calculus, applications to science
- Modern Mathematics (from 1700 CE to 1950 CE): modern abstract analysis, modern abstract algebra, modern abstract geometry, modern logical freed mathematics from the perspectives, paradoxes, and problems encountered during the classical and mercantile periods
- Post-Modern Mathematics (from 1950 CE to present times): dramatic expansion in scope and productivity in mathematics,

based upon axiomatic methods, accelerated by unprecedented growth in science, applied science, engineering, technology, statistics, and applications to all areas of human endeavour.

It is evident that the development of practical mathematics is basically dependent over the periods and especially during the modern mathematics and post-modern mathematics periods where the application of mathematical knowledge in every field has inspired and served as the basis of all developments, technical and scientific inventions. Moreover, practical mathematics application had led to the development of inter-disciplinary perspectives leading to development, innovation and research.

Scope of practical oriented teaching of mathematics

There are numerous instances where practical oriented teaching of mathematics may well be seen as a more appropriate teaching strategy by presenting concepts practically with the help of an aid for student's participation in a practical activity to help the student perceive the subject better. This helps them in understanding the concepts much better when compared to theoretical teaching. Gagne (1975) opined that the aim of practical oriented teaching of mathematics is to develop better concept formation, which helps even the slow and average learners to learn mathematics in a better way. The following objectives of practical oriented teaching of mathematics will have a constructive influence in the teaching learning process.Awareness about practical oriented teaching of mathematics will serve as a boon in the instructional process.

- Once the many benefits and rewards of practical oriented teaching and learning of mathematics is perceived, it encourages schools to set up mathematics laboratories.
- Practical oriented teaching and learning of mathematics will prove to be an explorative facet with the application of educational technology.
- Present day technologies like augmented reality, virtual interfaces, and artificial intelligence, which are the future of learning mathematics, will turn to be completely based on practical aspects.
- Practical oriented teaching of mathematics creates a scope for exploring, verifying and experimenting on mathematical results by students themselves (NCF, 2005) thus, highlighting the scope of mathematics learning through practical means.
- Provide the learners the scope for interaction, communication and representation of mathematical ideas by practising processes (NCERT, 2018).

Much of the mathematical concepts that involve logical / symbolic operations are perceived to be abstract, where in with the practical oriented teaching of mathematics, the concept formation process concerning these abstract areas in mathematics may be divided into parts keeping the perceived difficulty of the slow and average learners. While conducting the present study, teachers have, at many instances, where they were expected to teach mathematics practically, have complained about lack of time, lack of resources, accessibility, etc. They questioned the essential availability and demands of the resources and the feasibility of carrying out practical teaching for all the important areas of mathematics, for the entire academic year and questioned the practical difficulty and the possibility of teaching a part or the entire syllabus practically.

Studies carried out by Macleod & Golby (2003) reveal that average learners have done much better in mathematics when they are taught through activity / practical methods. This improvement is attributed to their improved conceptual understanding of the subject which they learnt through practical means and the teacher's effort in breaking up complex problems into simple and concrete ones.

At the secondary level, the curriculum context, with regard to mathematical concepts, diverge in forms, difficulty, abstraction and logic. Hence, many students, from this level find mathematics a difficult subject. In the present day context, both the culturally and socially widespread attribution that had affected the mind-set of students from the beginning stages of learning mathematics has been widely interpreted as, "mathematics is a difficult subject to learn and unless there is additional or extra coaching it is impossible to learn mathematics on their own" – (US National Research Council, 2001). This was found to hold contextual significance in the pursuit of this research.

Deductive nature of practical mathematics

Practical mathematics focusses on logically deducing facts and figures to arrive at a sequenced approach in understanding and solving a problem, right from the point of conceptual understanding till problem solving. Mathematics is a deductive science, which is based on proof and discovery. The deductive nature of mathematics aims at acquiring knowledge by looking at examples and inferring to form an idea to arrive at what may be true in general. Generally, this involves forming a conjecture, which is a statement that represents the inference of the idea conceived.

Wohlgemuth (2003) states that deductive mathematics asks questions about what is true about this thing being studied? and how do we know that it is true?

It may be observed that the problem section of mathematics texts for students and teachers involve primary problems, which is basically deductive in nature. This is evident from the following examples pertaining to upper primary level, which highlight the deduction process involved in comprehending and solving a problem.

- All numbers ending in 0 or 5 are divisible by 5. The number 35 ends with a 5, so it must be divisible by 5.
- Deduction is drawing a conclusion from something known or assumed. This is the type of reasoning applied in every deductive mathematical argument. For example, to solve $3x = 9$ for x we divide both sides by 3 to get $3x/3 = 9/3$ or $x = 3$. What we know or assume is that $3x = 9$ and that you can divide both sides of an equation by any non-zero number and the equation is still valid. From these two facts we deduce that $x = 3$.

In simple terms, deductive mathematics aims at arriving at a conclusion based on the premises of assumption. For example, given two statements that x is equal to y and y is equal to z, by deduction it is concluded that x is equal to z.

Mathematics learning and achievement is dependent on factors such as conceptual understanding, need for practical activities in mathematics learning strategies, such as participation, activity-based learning, laboratory activities, etc. (Fernandez, 1997). Similarly in the context of mathematics, teaching the following strategies play a vital role: a) conceptual understanding of the core knowledge required in the practice of teaching; b) fluency in carrying out basic instructional routines; c) strategic competence in planning effective instruction and solving problems that arise during instruction; d) adaptive reasoning in justifying and explaining one's instructional practices and in reflecting on those practices to improve them; and e) productive disposition toward mathematics, teaching, learning, and the improvement of practice (US National Research Council, 2001).

- Practical orientation towards teaching of mathematics provides an opportunity for the students to discover through activities that are relevant in mathematics learning.
- While carrying out the activities, students learn to analyse the problems by understanding the concrete and abstract nature of the problem, which helps to differentiate where more understanding

should be applied.

- Practical learning of mathematics gives scope for student participation both individually and as a group. It enables students to become more active as autonomous learners.
- The experiential aspects of learning happen only when there is scope for practical learning of mathematics.
- A simple practical activity will give them a concrete understanding of the concept that once they found difficult to learn.
- Puzzles, games and simple subject-based activities help the learners learn concepts in mathematics starting from the very basic classes to the higher levels. Practical learning provides scope for experiential understanding of the subject.
- Practical learning of mathematics helps in enhancing the student's interest towards learning the concept through an activity by which there is a scope for finding out the practical relationship between the problem and the solution.
- More importantly, the dependencies and independent learning sense, apart from the common classroom set-up gives them a sense of achievement interest and confidence.

ICT tools and practical oriented teaching of mathematics

In the present day context, many mathematics teachers have widely started using ICT-based learning modules or applications to teach concepts that require practical orientation. This provides students with a better understanding of the subject by virtual modelling, which may be referred to also as mathematical modelling. Agyei & Voogt (2011) highlighted that the ICT applications that are widely used in mathematics teaching learning process include portables, graphic calculators, computerised graphing, specialised mathematics software, programmable toys, spreadsheets, databases and mathematics-based gaming applications. These, however, need to be in the context of the child and include conversations, dialogue, discovery and problem solving. It is not the use of materials and equipment but more the thinking and the work done on the same.

Using ICT components take practical oriented teaching of mathematics to the next level. Still, it is a virtual model based on ICT principles, which may be well suited for higher classes. At the middle school level, where the development of concept is still at a passage from iconic to symbolic, concrete objects / visual objects play a better role in teaching mathematical concepts (Bruner, 1961). Adopting ICT tools helps teachers implement practical oriented teaching of mathematics in the following perspectives.An integrated approach to deliver topics in mathematics using various software, applications and multimedia-based presentation tools. This must include the active participation of learners in conceptualisation, abstraction and articulation of their understanding.

- Virtual mathematics laboratory should be made possible and practical activities that are relevant to each level should be made available using interactive tools and augmented reality applications. In this, tasks of visualisation and building new examples that would exercise the mind of the learner are needed.
- Developing programmed content especially for practical based concepts in mathematics using one or more ICT-based tools benefits enhanced usage of the ICT-based applications in practical learning of mathematics.
- ICT tools such as infographics, data visualisation techniques such as Google Charts, Tableau, Grafana, Chartist, js, FusionCharts, Datawrapper, Infogram, ChartBlocks and standard mathematics learning resources such as Wolfram Alpha, GeoGebra, ConceptuaMath, Thinking Blocks, FunctionVisualizer, etc. extend their resourcefulness in enhancing practical oriented teaching and learning of mathematics.

All these need to include new problems and tasks that expect the use of the concepts through the tools. The use of the tools is a means and not the purpose of the classroom.

Conclusion

Practical oriented teaching of mathematics can be viewed as a potential method of teaching mathematics effectively. High school level is considered a transition point in learning – shifting from the basic and concrete concepts to abstract concepts, problem solving from knowledge and understanding level to application and skill level involving higher order thinking skills.

In this stage, many aspects of how a pupil learns, the conceptual understanding process and many other cognitive aspects of mathematical problem solving ability are still unfamiliar to mathematics teachers. Teaching mathematics practically will help teachers in recognising the intricate, complex and convoluted process of how conceptual understanding takes place and the approach to problem solving. Thus, by initiating to view mathematical concepts through a practical viewpoint, it may become a rewarding attempt to hone the conceptual understanding and problem solving ability.

NCF (2005) highlights that, "the major objective of mathematics education is mathematization of the child's thought process." This is reflected in many research studies that were carried out in related areas such as mathematical problem solving, activity-oriented teaching learning, heuristic approach and other teaching approaches that are aimed at improving conceptual understanding of mathematics. It may be noted that there is an imperative need to teach mathematics practically, which contributes to the enhanced conceptual understanding and problem solving ability, which in turn unlocks leading possibilities in creating awareness and familiarising practical oriented teaching of mathematics, laboratory-based mathematics teaching and activity oriented teaching of mathematics.

Acknowledgement

This paper is part of the Funded Project titled, 'Practical Oriented Teaching of Mathematics in Enhancing Conceptual Understanding and Problem Solving Ability among Students Studying at the High School Level', carried out under Impactful Policy Research in Social Science (IMPRESS) and is supported by the Indian Council of Social Science Research (ICSSR) [ICSSR-IMPRESS: F.No.IMPRESS/P605/110/18-19/ICSSR dated 07.05.2019].

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