

Need for Equipping Student Teachers with Language of Mathematics

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Abstract

The significance of curriculum in building up language of mathematics which enables learners to construct and communicate knowledge of mathematics has not received due attention even as the pedagogical challenges faced by the students in learning mathematics have been discussed for years. Learning language of mathematics is not only valuable in itself but also useful in understanding other fields of knowledge especially science. It is contended that the use of devices of language of mathematics is even helpful in learning common languages especially in learning grammar, rhythm and versification too. It is clear that understanding the language of mathematics and its special terms as fluently as possible, among other benefits, releases the cognitive processes within the learner to deal with more useful actions including solving the problem. Hence, it is important that teacher education curricula build into it the components or elements of mathematics such that the structure of language of mathematics is understood by the student teachers. This paper discusses the importance of language of mathematics, its structure and significance in mathematics education. It further suggests ways for imparting understanding of language of mathematics to novices. In view of the relevance of language of mathematics in teaching learning, this paper also considers strategies that can be employed in equipping future teachers with necessary skills and competence to deal with language of mathematics.

Keywords: Teacher Education, Mathematical Vocabulary, Mathematics Learning, Mathematical Communication, Mathematical Sentence, Mathematical Statement, Mathematical Symbol

The laws of nature are written in the language of Mathematics...the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word.

(Galileo Galilei)

Introduction

Mathematics touches every aspect of life and hence is a significant aspect of human learning and knowledge. However, teaching- learning mathematics in schools fails for a variety of reasons. This has been extensively studied and explained from many perspectives. However, the problem of mathematics in schools persists. It is in this context that this paper approaches problem of mathematics teaching learning from the perspective of language of mathematics. Specifically the relation of language of mathematics to the perceived difficulties of learning it along with structure and characteristics of language of mathematics are examined. The means of imparting language of mathematics to children and its implications for teachers and student teachers are also considered.

Nature of school Mathematics

Mathematics holds a cardinal place in school curriculum everywhere in the world. Mathematics is used in everyday life. It has prominent role in learning and understanding almost all the disciplines. Counting, Proportion, Percentage has immense role in everyday life. Medicine, Banking, Commerce, Business, Health sciences, Music everywhere we are obliged to use mathematics.

Mathematical proficiency means the ability to understand, judge, do, and use mathematics. Such abilities are required both in contexts where one has to deal directly with mathematics as a subject as well as other in-school and out of school situations where mathematics plays or could play a role. These abilities in turn require lots of factual knowledge and technical skills. Many of these skills are related to vocabulary, orthography, and grammar necessary for learning, understanding and but not sufficient prerequisites for literacy (Niss, 2003).

National Focus Group on Teaching of Mathematics (NCERT, 2006) recommends that a special mention must be made of problems created by the language used in textbooks, especially at the elementary level. It further observes that for a vast majority of Indian children, the language of mathematics learnt in school is far removed from their everyday speech, and especially forbidding. This becomes a major force of alienation in its own right. Nevertheless, it is not a case of textbooks alone. When students enter schools, they are far removed from the language of mathematics than they are from the normal language of day-to-day communication. Hence, when children are introduced to the number concepts, units, and arithmetic operations they have not only to learn these processes but also to learn vocabularies, symbols, and ways of expressions in order to understand what the teacher is trying to communicate to them. Except for the words for the first few numbers, a child entering the school is practically ignorant of most of these concepts specific to Mathematics. While ideas related to other areas of knowledge can be communicated in languages familiar to the students at a level cognizable to the learner, mathematics requires a special language. This aspect however is practically neglected by teaching learning objectives, the classroom activities, and assessment practices of mathematics in schools at all levels.

Children learning mathematics can be considered being in double disadvantage. Compared to learning of languages, social sciences and even natural sciences, learning of mathematics calls for higher cognitive investment in learning concepts and principles, processes and related skills and specific language for communicating what is being learnt. This enhanced cognitive load in learning mathematics divides the cognitive energy in mastering mathematical concepts, processes and related skills and specific language for communication resulting in comparatively low attainment in all three or one or two of these focal areas of instruction. Students and teachers usually compensate the deficit in cognitive energy by focusing in mathematical processes and skill which seems to be for them unique to mathematics as a subject. However, cumulatively the low level of attainment in language specific to mathematics, and to some extent its concepts and principles, creates bottlenecks in learning even the mathematical processes and skills. This makes mathematics the most difficult subject being taught at school for majority of students. This failure to attain cognitive outcomes of learning mathematics results in affective reactions in learners, making them feel a negativity, anxiety, and fear of mathematics. In order to make mathematics attractive to students one of the major steps thus required is helping students master the

language of mathematics; but, teachers of mathematics usually focus on the mathematical competencies like having to learn the process of mathematics and its operations.

John Sweller (1994) suggests that Schema acquisition and automation are the primary mechanism of learning. Mastery over subject depends on these two processes. Schema is the basic unit of learning. Function of learning is to store automated schemas in long-term memory. Learners will need additional cognitive demands in solving mathematical problems due to the language used to present the problem. In most cases, learner will have the mathematical schema; but only when the process of automation starts to work one can use it. As working memory is very limited, automated schemas in long term memory will be helpful in reducing working memory load. Language acquisition should be automated, such that working memory can be used for solving mathematical problems and not for reading and comprehending the language of the problem.

Nature and structure of Language of Mathematics

To master mathematical language includes to understand and to interpret oral expressions of mathematics, to decode written and graphical representations of mathematical ideas, to express quantitative ideas and statements orally and in writing in varied contexts.

From the perspective of novice learners much of the Mathematical problems, processes and its results are expressed in a language alien from the more natural language that they use to learn other school subjects. Though neither the teacher nor the curricula explicitly states it, this language of mathematics like other languages has grammar, syntax, vocabulary, word order, synonyms, negations, conventions, idioms, abbreviations, sentence structure, and paragraph structure. Additionally, it has certain language features incomparable to other languages, such as representation, equations, process symbols and relational symbols. The language also includes a large component of logic. The concept, Language of Mathematics, lay emphasis on all these constructions of the language (Esty, 1992).

There is parallelism, though not direct, between language of mathematics and usual language of communication. Natural language, gradually expanded to include symbolism and logic, is the key to both the learning of mathematics and its effective application to problem situations. Use of appropriate language of mathematics, in ways that learners can comprehend, in teaching, learning and communication is the key to making mathematics intelligible. Indeed, truly, mathematics is a language. Proficiency in this language can be acquired only by long and carefully supervised experience in using it in situations involving argument and proof (Allen, 1988).

Not only is learning language of mathematics valuable in itself but also it is useful in understanding other fields of knowledge especially science. It is contended that the use of devices of language of mathematics is helpful even in learning common languages especially in learning grammar, rhythm and versification too.

Components of Language of Mathematics

It is common nowadays to use the phrase “Language of Mathematics”. Does Mathematics possess all the characteristics/properties of natural language? Language is a system of Communication made up of sounds, words, rules to form words and grammar to form sentences. Therefore, language is as a system of rules or conventions for communication in a social context. Likewise, mathematics also has a language to communicate mathematical ideas in a specialized way.

Components of a natural language can be enumerated as its Content, Structure and function. Content includes Lexicon and Grapheme. Vocabulary or lexicon is the basic

component of any natural language. Most of the natural language has its own grapheme which is the smallest unit used in describing the writing system of a language. Structure of language is governed by rules related to Phonology, Morphology and Syntax. Phonology deals with sound system of language while Morphology deals with the rules related to formation of words. Syntax is rules related to formation of sentence that we commonly refer as grammar in language. Then, there is the functional aspect of language - Semantics and pragmatics. Semantics patterns the meaning of words and sentences whereas pragmatics is system that outlines the use of language in context.

Keeping in mind the system of natural language, we can examine the language of mathematics. Language of Mathematics can also be made into components as Content, Structure and Function.

Mathematics has its own language with unique content that comprises grapheme and lexicon as natural language do (Figure 1). Mathematical grapheme includes something which is unique to mathematics viz., Diagrams, Numbers and symbolic expressions. Though we consider Mathematics as a universal language, some of the mathematical graphemes are not universal. For example, numbers have different written character forms in Arabic and Malayalam languages. Mathematical symbols can be classified as

- Object/Concept Symbols (Eg : Numbers)
- Operation/ Process symbols (Eg: Arithmetic operations)
- Relation symbols (Eg: perpendicular, Parallel)
- Auxiliary Symbols (Eg: parentheses)

Mathematical vocabulary/Lexicon includes verbal expression/ Terms, which can be broadly classified as Discipline specific terms, and common words that have a different meaning in mathematics. For example, Sign, Volume, figure, odd, face have a different meaning in Mathematics. Mathematical lexicon also includes variables, Numbers and Symbolic expression.

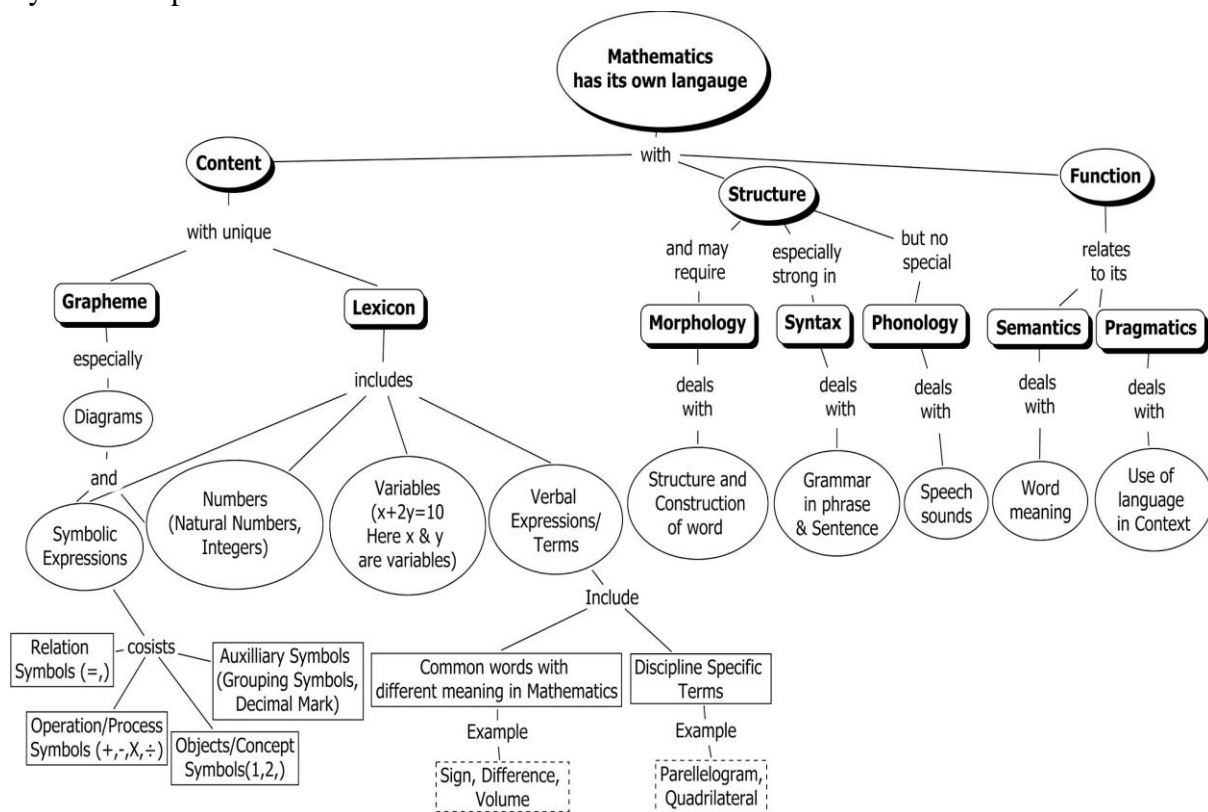


Figure 1: Components of Language of Mathematics

Unlike natural languages, mathematics has no special phonology to deal with speech sounds but require morphology to deal with grammar in formation of words. A number of mathematical terms has prefix from Latin or Greek. Morphological study of such mathematical terms will upturn the level of comprehension of mathematical vocabulary. Structure of mathematical language also deals with Syntax that constitutes rules related to sentence formation. Mathematical sentence has its own grammar. For example, an equation is a mathematical sentence with noun as expression and verb as “=” (is equal to).

The third component of language of mathematics is the functional aspect of language - semantics and pragmatics. Semantics concern with meaning of Mathematical terms whereas pragmatics deals with the contextual usage of mathematics. Mathematics teachers need to be more concerned with morphology, semantics and pragmatics of Language of Mathematics.

Though Mathematics is considered as a non-linguistic subject, it has many similarities with Language. However, we cannot consider mathematics as a mere language only. Mathematics possesses most of the properties of natural language with some specialities exclusively for mathematics. Mathematics is the most economical language, as it is so precise and brief in its usage.

Objectives of Language of Mathematics for schools

From a learner perspective, Language of Mathematics is not much easy to learn and demands continuous effort from the learner as much as to learn a second language. The major abilities the students have to acquire in relation to language of mathematics are *understand, use, analyse, create and judge* mathematical symbols and formalisms, switching from natural language to formal symbolic language of mathematics, and vice versa, in addition to understanding and using mathematics statements. Language of mathematics required by students in schools also includes handling mathematical symbols and formalisms. In this regard, students have to learn decoding and interpreting symbolic and formal mathematical language, and understanding its relations to natural language. Understanding the nature and rules of formal mathematical systems (both syntax and semantics) is part of learning language specific to mathematics. Just as learning a second language requires translating ideas from own language to the second language, learning language of mathematics also involves translating from natural language to formal/symbolic language.(Niss , 2003; Vintere et al, 2014)

Language of Mathematics allows one to handle and manipulate statements and expressions containing symbols and formulae (Niss, 2003). Mastery of the language of mathematics is demonstrated if the learner is *Communicating* in, with, and about mathematics such as *understanding* others’ written, visual or oral ‘texts’, in a variety of linguistic registers, about matters having a mathematical content; *expressing* oneself, at different levels of theoretical and technical precision, in oral, visual or written form, about such matters (Niss, 2003).

By instructing the language of mathematics, learners acquire not only the ability to *ask and answer questions* in and with mathematics. This is a very valuable outcome from the point of view of school, teachers, and learners. This develops *ability to deal with and manage increasingly complex mathematical language and tools* for future use.

Ability to ask and answer questions in and with mathematics which is expected from learners in every mathematics classroom calls from the learner's, ability to *Think* mathematically, *Pose and solve* mathematically, *Model* mathematically, and *Reason* mathematically. Thinking mathematically requires ability to pose *questions, understand* and

use the scope and limitations of a given concept, *extend the scope* of a concept, and *distinguish* between mathematical statements. Ability for posing and solving problems mathematically requires ability for *identifying, posing, specifying* and *solving* different kinds of mathematical problems.

Modelling and Reasoning mathematically, as the names indicate, are more complex skills than earlier ones. Modelling mathematically, is by *analysing* foundations and properties of and *decoding* existing models, *performing* active modelling in a given context. Reasoning mathematically involves *following* and *assessing* chains of arguments, *knowing* what a mathematical proof is (not), *uncovering* the basic ideas in a given line of argument, *devising* formal and informal mathematical arguments, and *transforming* heuristic arguments to valid proofs. (Ongstad, 2007)

Ability to deal with and manage mathematical language and tools involves *representing mathematical entities* and making *use of aids and tools*. Representing mathematical entities requires understanding and utilising different sorts of mathematical representations, understanding and *utilising relations, choosing* and *switching* between representations. Making use of aids and tools requires knowing the existence and properties of tools for mathematical activity, *being able to reflectively use* such aids and tools (Ongstad, 2007).

Implications of Language of Mathematics for educational Practice

Fisher and Frey (2004) explain that learning is language based. Telling students information is not sufficient. Students must *think* about, *read* about, *talk* about, and *write* about information in order to *synthesize* it and to retain it. Reading and writing are critical to all learning. In view of the relevance of language of mathematics in teaching learning, strategies that can be employed in equipping future teachers with necessary skills and competence to deal with language of mathematics are discussed.

Student teachers should *analyse, compare* and *discuss* about the features of language of mathematics, especially in relation to natural languages and other discipline specific languages, say for example language of sciences.

Justice Varma commission report 2012 evaluates that most teacher education programs do not adequately engage with subject knowledge. An exploration of how a layered understanding of subject knowledge frames pedagogic encounters and influences learning rarely enters rarely enters into the process of preparing teachers. Taking the case of Mathematics teaching, providing academic support in learning language of mathematics is important. Hence, it is important that teacher education curricula build into it the components or elements of mathematics such that the student teachers understand the structure of language of mathematics.

To become familiar with the vocabulary or fluency in using vocabulary of language is important in becoming proficient in that language. Vocabulary is a major contributor to overall comprehension in any content area. One of the commonly used strategies for vocabulary development is the one developed by Marzano (2005) as listed below, where in First 3 steps introduce and develop initial understanding, and last 3 steps – shape and sharpen understanding.

- 1) Provide a description, explanation, or example of new term.
- 2) Students restate explanation of new term in own words.
- 3) Students create a non-linguistic representation of term.
- 4) Students periodically do activities that help add to knowledge of vocabulary terms.

- 5) Periodically students are asked to discuss terms with one another.
- 6) Periodically students are involved in games that allow them to play with terms.

Teachers can use variety of methods in order to improve mathematical vocabulary in their students like Root Word Tree, Sharing Mathematics, Vocabulary Flip Book, Content Links, Alike and Different, Total Physical Response, Math Hunt, Mathematics word wall, Frayer Model, Vocabulary Self-Collection, Possible Sentences, Guided Free Write, Vocabulary Journal and List-Group-Label.

As National Focus Group on Teaching of Mathematics (2006) advocates, school mathematics takes place in a situation where children see Mathematics as something to talk about, to communicate, to discuss among themselves, to work together on. Building Mathematics as part of children's life experience is the best Mathematics education possible. For this, teachers should be made aware of importance of considering mathematics as language as well as a non-linguistic subject and of giving sufficient importance in finding time to teach linguistic aspects of mathematics in classroom teaching. Only then student teachers can demonstrate distinctive features of mathematics that make it the most efficient and precise way of expressing knowledge.

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