Language learning as a learning model for mathematics, science and technology

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Abstract

The relationship between language and learning has received attention in the learning of mathematics, science and technology. The focus has been on the role that language play in learning, or the relationship between language and thought with implications on learning. What has not received focused attention is how far the way language is learned, in particular, first language, can serve as a model for the learning of other logical systems. An underlying assumption is that there is a considerable amount of success when children acquire their first language. Paying a closer attention to the processes involved provides an interesting line of thinking in terms of how the learning of Mathematics, Science and Technology (MST) can be enriched. This is provoked by the fact that research reveals that achievement in terms of learning in these fields is not where it should be. There is room for improvement. This study seeks to lay a basis for the investigation of a learning model for MST based on how children learn what comes to be considered as their first language. The paper takes a closer look at "activity-based learning" as an approach in the learning of MST and compares and contrasts this to how children learn a language. Constructs that are built, such as discovery versus generativity, provide insight into how the teaching of mathematics, science and technology can be improved.

Theoretical background

The teaching and learning of mathematics, science and technology is a problem in South Africa because its success rate is low. This paper attempts to present ideas from a study that was part of a Masters degree programme. The thesis suggests that in order to bring about an improvement in the learning and teaching of mathematics and science, language learning should be investigated as a learning model. The study is an attempt to put forward a proposal for a model for the learning of Mathematics, Science and Technology (MST), based on the learning of language, especially mother tongue (L1). The argument is that the way mother tongue is acquired provides a way to successful learning. Furthermore, language and MST share a number of common features amongst which is the complexity of their structures.

A survey of literature makes it possible to identify those features (of language) that make first language what it is and how it is learned. These include features like the relationship between language and learning and language and thought.

It is also interesting to note that the work that has been done so far around the relationship between language and logic provides some evidence that language; mathematics and
science can be seen as similar systems, which operate on and consist of similar structures. Partee and Hendriks (van Benthem and Meulen, eds: 1997) indicate that Montague’s greatest contribution to this area of language and logic is that of bringing an understanding that syntax and semantics should be seen as algebra. They further define language (within this framework) as:

"...Language, in the simplest case, is the set of all expressions which can be formed by starting from some basic expressions (the generators of the algebra) and applying operations in all possible ways; that is, it is the closure of the generator set under the operations of the algebra." (P18)

Osherson et al (van Benthem and Meulen: 1997) did a similar comparison, this time between language and science. They state that:

"Like the child, scientists typically have limited access to data about the environment, yet are sometimes able to convert this data into theories of astonishing generality and (apparent) veracity. At an abstract level, the inquiries undertaken by child and adult may be conceived as a process of theory elaboration and test. From this perspective, both agents react to available data by formulating hypothesis, evaluating and revising old hypothesis as new data arrive.... It is evident that both forms of empirical inquiry - achieved spontaneously in the early years of life, or more methodically later on- are central to human experience and cultural evolution." (P739).

In a journal for Research in Mathematics Education, McGregor & Price (1999: 451) investigated the relationship between language proficiency and the learning of Algebra. They assert that

"Because analyzing structure, making choices about representation and manipulating expressions are intrinsic to mathematics, and particularizing to algebra, it seems likely that metalinguistic awareness in ordinary language has an equivalence in algebra".

These claims have implications for the thesis maintained in this study. One being that the relationship between language and learning is more than instrumental. Another being that a good and deeper understanding of language structures, not just a memorization of grammar rules but an insightful understanding of the patterns is a basis for better performance in algebra. McGregor & Price (Ibid) add impetus to the point that the structure of algebra is very close to the system of rules that govern a language, grammar.

These allusions to the similarity between the learning of language and mathematics and science should add as evidence that language can be understood as being very close to mathematics and science. This should then give room to the speculation that the way language is mastered should serve as a model that we should employ to master the content in mathematics and science, to ensure a high level of success.

**Language and thought**

In an attempt to lay a basis for the ideas that are to be developed and to be used in this argument, the relationship between language and thought has to be explored. There is an interesting debate about which of these faculties develops first, that is, linguistic ability first and then thinking; or the opposite. Bowerman (1976, 1978) reviews questions regarding cognitive organization as quoted in Rice (1980). This insightful review leads to two
interesting conclusions that are in direct opposition. One is that language and cognition are independent of one another in both source and development. The second is that language development is dependent on cognitive development.

It is necessary to trace the roots of these claims. The first one is a product of the wealth of knowledge that Chomsky unveiled to a number of disciplines in his study of language. Radford (1988:3-4) supports this by asserting, "Children are born with a system of principles and parameters that determine the form of natural language." This is Radford's way of elaborating on Chomsky's notion of the Language Acquisition Device (LAD). The second conclusion springs mainly from Piaget's work on cognitive development, which is seen as an alternative to the LAD postulation. This stance was then labelled the 'Strong Cognitive Hypothesis' (Rice, 1980:10).

Rice (ibid.) summarizes this stance when he says, "Language builds on a cognitive base, and concepts are regarded as prerequisites for subsequent language skills".

The arguments above reveal the point that there is a close relationship between language and thought, but one that is not easy to pin down. Bickerton (1995:160) comments: "… The architecture of cognition, or at least that part of it that is peculiar to our species, lies within language, and human cognition has the properties it does have precisely because it came out of language, and not vice versa."

He adds and says

"I am talking about the infrastructure of language: the properties and consequences of the system of neuron ensembles and connecting nerve fibres that made possible first, the first and only symbolic system for transmitting objective information that emerged on this planet; and second, the refinement of that symbolic system whose use we enjoy today."

The many contributions to the language-thought relationship are important to the thesis in this work because it emphasizes the point that language is not to be seen only as a means of communication. There is more to it than that. It is a well-demonstrated fact that language is a tool for conveying knowledge and information. Halliday's work (Halliday, 1973) on the functional approach to language helped largely in providing ways of exploring this side of the nature of language. Yet, this is only a part of what should constitute our understanding of what language is.

The language-thought debate exposes another important nature of language, that language 'is a mirror of the mind' as Chomsky points out (Radford 1988: 1). Rice (Ibid: 3) states that "the scientific study of language as a means of furthering our understanding of mental processes has proved to be overwhelmingly productive…." Bickerton (ibid: 161) argues that "only through an understanding of language will we ever understand ourselves". McShane (1991) goes a long way to indicate that his "Information Processing model"(a model for learning) of learning, is based on the understanding that the cognitive system is the basis for all mental behaviours. He argues that

"When the effects of the brain's processing of information can be observed as behavioral measures, it is possible to make inferences about what the functional organization of the brain must be like in order for behavior to be as observed."
McShane adds that "the inferred functional organization of the brain is referred to as the cognitive system" (McShane, 1991:14). It becomes clear in this paradigm, that language is seen as part of what the mind has to work on, and not as constituting the mind. McShane also states that "the information to be processed by the mind covers a wide range, from basic perceptual information to the information contained in complex symbolic expressions". This suggests that language is included as part of the 'symbolic expressions'.

It is worth reiterating that there is more to language than just seeing it as a means to serve a number of functions in the communicative sense. A closer investigation of language will reveal a lot more, essential for a better understanding of the human life, with learning being part of this human life.

**Language and learning**

One more vital point to note about the language-thought relationship is that there exists a close relationship between language and learning in general. The relationship springs from the point that learning is closely tied to thought, thinking, the mind or cognition. This relationship goes deeper than the idea that language is used in learning. Piaget's ideas of equilibration, taken up by Ausubel (1978) in his theory of 'Subsumption' in meaningful learning, Brown (1994:84), reveals that what we do as we learn language is what we do and have to do when we learn other bodies of knowledge. It therefore becomes impossible to separate language from the process of learning. This is also evident in the point that psychologists and other theorists who focus on how the mind works, especially in the area of learning, are unable to talk about issues in this field without touching on language. This has cut across theoretical paradigms, from such behaviourists as Skinner in his work: Verbal behaviour, to cognitivists as Piaget who theorized that cognitive development is a prerequisite for linguistic development. Ausubel (1978), Halliday (1973) and Brown (1994), amongst others, failed to separate learning and language. There is always a crossing of paths between what language and learning entails.

Katherine Nelson (1996: 40) echoes these sentiments when she states that "cognitive development is not separable from language, and the reverse is also true." This assertion comes after she supported Wierzbicka's (1994) complaint that modern mainstream psychology at times seems to behave as if language is irrelevant to the study of the mind. She further asserts that there is no way in which cognitive development, which also involves learning, can be fully understood without putting language at the forefront. The connection between language and learning cannot be reduced to a functional level. Wells also argues that the relationship between language and learning is of importance when he argues that:

"… as in learning to talk, however, the child will be helped most effectively by the teacher strategies of guidance and contingent responsiveness". (Wells & Nicholas (eds.), 1985: 39)

Wells was referring to learning in general, within a formal set up of a teacher and learner. In this way the relationship is even pushed further because he claims that learning (as in the learning of other forms of content) is an imitation of the process a child undergoes when acquiring mother tongue.

**The process of language learning**

Language is not a habit structure. It is innovative. This is one the many Chomskyan notions that have uncovered a lot of understanding in linguistics as a science; and also provided other disciplines with constructs for study and use. Radford (1988:18) states that "when a
child learns a language he does not imitate, but create rules (formulas) which further structures utterances. He adds that

"A child learning a language and faced with a certain set of data (the speech of people around) abstracts from the data a set of general principles about how sentences are formed, interpreted and pronounced. These principles or rules must be of a sufficiently general nature to allow the child to form, interpret and pronounce new sentences that he has not come across."

This process reveals that language learning is a demanding task, one that engages the mind in a number of operations. McShane (1991: 14) describes the job of the cognitive system as to process, store and retrieve information. He indicates that others involve "categorization, generalization, induction, association, hypothesis testing and meaning analysis." Radford's description of what happens when a child learns a language appears to correspond with McShane's description in the learning processes (generalization - induction - association).

It becomes very interesting to think of a three year acquiring a set of syntactic rules, which specify how sentences are built out of phrases and phrases out of words. The child does not imitate what others produce, but generates own formations. This is evident in the kind of errors children make. The errors reveal that children apply the rules they have built for themselves, and internalised. It is important to note that utterances children are exposed to in language learning, do not reveal the underlying rule system. What they get is the output of applying the abstract rule system. They continue to construct their own rules. This relates to normal children as they get exposed to L1.

The following diagram illustrates the situation mentioned above:

Activity-based learning

This study also focuses on Activity-based learning as a method used in the learning of mathematics, science and technology. An investigation into how language learning and Activity-based learning compare and contrast will be useful in determining if there are aspects or processes that can be transferred for the benefit of teaching and learning mathematics, science and technology. This study will focus on Activity-based learning because it is hailed as one of the best ways of learning and teaching, especially in mathematics and science. Activity-based learning is assumed to be built on the rationale that children learn best when they do or are involved in action. Learning is then structured into 'activities' that will facilitate what has to be learned. This specific approach is closely related to "discovery based learning' and 'inquiry based learning', all of which are linked to methodology in 'Outcomes based education'.

The rationale on which Activity-based learning is founded is further strengthened by Constructivism. Roth (1995:12) writes that 'The core of constructivism is the belief that human beings build up knowledge in a slow process, that begins with simple sensory-motor schema during early childhood and progresses to complex schema without physical referents from the late teens onwards.'
It is worth noting that there has already been some importing of linguistic learning strategies into the learning of the sciences, as the interest in this study lies on investigating what can be transferable from language to mathematics and science. The Information processing model of learning supports this claim, (McShane, 1991). In developing an approach like this, McShane makes the following claim:

"The information to be processed by the mind covers a wide range, from basic perceptual information to the information contained in complex symbolic expressions". (P14).

The argument that this study would like to pursue is that even though activity-based learning is considered a powerful tool within the learning of mathematics and science, it is still not able to take learners to the desired level of performance. It has to be supplemented in some way if it has to lead to attainment of the desired goal. The researcher believes that the approach needs to be supplemented by using principles of language acquisition.

In the proposal for the establishment of Mastec (a specialist college for mathematics, science and technology education in the Northern Province, South Africa), a submission to Cotep (Committee on Teacher Policy), there is a call for new approaches for the Mastec curriculum, ‘with an emphasis on hands-on experiences in an exploratory mode’. (Cotep document: 15). Activity-based learning becomes a relevant teaching approach in this environment.

Data that was collected at this Education College (Mastec) has helped to provide a comparative forum for language learning and the learning of mathematics and science. The data was collected through a questionnaire to students, class observations and lecturers’ interviews. Statistical data from Mastec composite end-of-year results served as instruments for secondary analysis. What came out is that Activity-based learning is a good learning approach that provides learners with strategies to interact with principles in the subject content. This study would like to argue that interacting with the principles and concepts is not enough. What seems to be missing is the point that the outcomes that have to be achieved should not be limited to discovery. Learning and teaching need to go beyond this point. The discovered principles should be used to generate new knowledge.

A challenge is posed against Activity-based learning, and as such against Constructivism too. The challenge is that in the approach, learning outcomes are aimed at the discovery of scientific principles only and not necessarily at the generation of further knowledge.

**Summary**

Language is rule-bound. In comparison, the structure of Algebra is very close to that of language. Language is not imitative but creative and generative. Children generate rules that they use to generate intelligible utterances. This process is similar to what happens in knowledge formation in the pure sciences. As in language learning, what is available and known is experimented with in order to produce that which is novel.

It has already been argued that language acquisition is generative. The child does not receive ready-made rules from those who already know the language. Correct utterances from these users of language form the data that a child uses to formulate rules. It is those rules that will then be used to produce novel utterances. Some of the utterances by the child will be incorrect in terms of adult grammar. The process of learning will go on until the child is able to produce correct utterances almost at the level of the matured speakers. It is this process of rule formation and rule application that demonstrates generativity in language learning. The learning of MST should borrow from this process if a high level of achievement
is to be attained. The notion of generativity also helps to indicate that language learning is not dependent on rote learning. The child does not memorise utterances from others to repeat later. What the child produces are novel sentences.

Alternative conceptions in science seem to have similar features as in the case of alternative rules in language learning. Correction does not come through substitution as it has already been argued. Alternative rules in language are an indication that learning is in progress. When a child produces ungrammatical utterances informed users (of the language) know that it is only a matter of time before they will be corrected. The child cannot be judged as having ‘failed’ in learning his or her mother tongue. The same attitude should prevail towards alternative conceptions in the learning of MST. Learners should not be written off as it usually happens. A lot of learners drop out of science classes because they were never led successfully to develop principles that will lead to the creation of authentic knowledge, a process that allows for the formation of alternative conceptions and the remedying thereof. From language acquisition studies it is established that all normal children succeed in learning their mother tongue if given the necessary exposure, it is all-inclusive. The learning of MST does not have to be as exclusive as it has been made.

In learning MST knowledge gaps that breed from insufficient exposure to scientific principles should be closed in a similar way as in language learning. Knowledge gaps can lead to overgeneralization, where a particular rule is applied to instances that are not relevant. A linguistic example is where a child adds (-s) to all nouns in order to form plurals in English. Correcting one word does not help. The child will not memorise the correction. What is needed is enough data to demonstrate to the child where variants occur. If children were to be taught the variant forms individually, there would be a great need for memorisation. But because language has a different way of being learnt, children end up mastering the variant forms and alternative rules get replaced. Alternative conceptions should be treated the same if remedying them is to be completely successful.

The constructs of generativity, time, alternative rule formation and the remedy thereof, the formation of knowledge gaps and how they have to be filled are what should form a basis for the understanding of teaching and learning in MST. These considerations should inform any endeavour to provide for learning and teaching that is meant to achieve the highest level. They should also be used to analyse all the activities geared at such endeavours.

**Limitations**

This study faces several limitations, one of which relates to the differences that exist between language as a system, and mathematics and science as knowledge systems on the other hand. These differences are acknowledged although investigating them is not the focus of this study. The similarities that exist, as cited from various sources, provide the premise on which this study calls for strategies and techniques to be transferred from language learning to the learning of mathematics, science and technology.

There are differences again between mathematics and science, which the study does not aim to overlook. What is of importance to the study is that these fields are commonly associated as belonging together. One common argument is that science students should be mathematics students. The reason given being that for a better chance of success the two have to be studied together since they supplement one another. There are also lots of concepts that cross the two fields.
References