Meta-cognitive Strategies in Problem Solving for Children with Learning Difficulties in Mathematics at the Primary Level

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Abstract

Many International Organizations have pledged for education for all children irrespective of gender, race, social background, disabilities or any such factor. Mauritius has joined the international move and has taken a number of initiatives to facilitate education for all children, including those with special needs. It has been found that our mainstream classes at the primary level do include children with learning difficulties in mathematics. Taking into consideration the importance of mathematics in the school curriculum and opportunities that it offers for further education and job opportunities in Mauritius, it is imperative to develop ways and means to help these children in their learning of mathematics. A strategy training program comprising of cognitive and meta-cognitive elements to solve word problems in mathematics has been designed and a sample of Standard IV pupils have been trained with this program. Data obtained from pretest and post-test and observations conducted through the training sessions have shown that this strategy training has been effective in helping children with learning difficulties in mathematics in problem solving. It has also helped these children to develop a positive attitude towards mathematics and have successful experiences with mathematics. These children need to be given opportunities and guidance to overcome the barriers to education and teachers need to have positive expectations from these children and provide all the necessary support to help them.

Introduction

The education for all children has been the concern of many nations for quite some time. All children are not the same; some learn fast, some slow, some need manipulatives while others prefer other modes. Some have difficulties in reading, some in mathematics while others in other subjects. Our normal system of education places children with learning difficulties at a disadvantaged position as compared to those who can cope with the system. This result in them lagging behind and ultimately dropping out of the system. Much needs to cater for the needs of these children and support them in their learning. Some children have difficulties because of impairments or deprivation but they too need to be given the opportunity to succeed in life through appropriate education. Teachers need to find ways and means where these deficiencies could be dealt with to ensure that these children too have the opportunity to develop their full potential. The right to education for every individual can be argued to be of prime importance and can be traced down to Universal Declaration of Human Rights (1948), World Conference on Education (1990), Convention on the Rights of Child (1989) etc. Race, gender, economic status cannot act as a barrier to education and more so a disability that a child has. Each and every education system needs to ensure that equal opportunities are given to children with disabilities for their education. We refer here to the United Nations Standard Rules on the Equalization of Opportunities of Persons with Disabilities (1993). The commitment to Education for All was further reaffirmed in World Conference on Special Needs Education (1994) in Salamanca, Spain. Mauritius, as many other countries in the world, has adopted policies aiming to promote the rights of children and, especially, children with disabilities to full and equal participation in society. It has ratified the Convention on the Rights of the Child in 1990.

The provisions and principles of The Convention on the Rights of the Child advocate for the protection of children rights and to help them meet their basic needs and expand their opportunities to reach their full potential.

Concern for children with special needs in Mauritius can be traced back to 1978 in the Report of the Commission of Enquiry in post-primary and secondary sectors of Education: The Road

Ahead (Special Education Needs and inclusive education in Mauritius: The policy and strategy document, 2006). Several reports which followed have consistently emphasized the need and concern for the education of children with special needs. Several legislations have been passed in Mauritius to help children with special needs in their education and their integration in the society. These include Child Protection Act (1994), Training and Employment of Disabled Persons Act (1996), Ombuds person for Children Act (2003), Education Act (Amended 2004). A number of Units have been created to help these children and these include The Association de Parents d'Enfants Inadaptés de L'île Maurice (1970), The Centre d'Education et de Développement des Enfants Mauriciens (1972), The Bethleem Diocése Crèche (1979), The Centre d'Education et Développement des Enfants Mauriciens (1984), the Child Development Unit (1995), the Ombudsperson for Children's Office (2003), the Observatory for the Rights of the Child, the National Children's Council. Several facilities are also provided to help children with special needs which include financial support and provision of equipments like wheel chair, hearing aids and white canes. It should be noted that education is free from the pre-preprimary, primary, secondary and tertiary levels in Mauritius (except for the private institutions). Furthermore, transport is free for all students. Buildings are being retrofitted to facilitate access to people with disabilities and special parking zones reserved for these people.

Based on my 22 years experience as a teacher trainer with different groups of primary teachers (both pre-service and in-service) and through interactions with them, I found that there are students who experience difficulties in learning mathematics at that level. The percentage of passes at the Certificate of Primary Examination (CPE) level for the past 12 years is shown in Table 1.

Table 1: Percentage of passes in the CPE examinations

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% passes	63.4	65.3	68.5	66.2	67.4	68.1	68.5	68.6	68.8	74.8	72.9	74.2

It can be found that around 30% of the children taking part at the end of the primary examinations do not succeed. This trend has been so for many years and this is a matter of great concern for all stakeholders in Mauritius. Many steps have been taken ranging from introduction of different projects (for example, Enhancement Program, Summer School) to the development of a National Curriculum Framework and reviewing of all curriculum materials at Primary level.

The percentage of passes in mathematics at the CPE level for the past 12 years is shown in Table 2 below.

Table 2: Percentage of passes in mathematics in the CPE examinations

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% passes	73.9	73.1	73.6	72.6	75.8	77.1	76.2	75.9	77.9	80.7	78.0	80.1

An analysis of the data shows that around 20-25% of the students taking part in the primary mathematics examination fail during the past twelve years. However, around 53% of the students score a maximum of grade C in mathematics at that level (Hurchand, Ramful, Bholoa & Nenduradu, 2012). This shows that a significant percentage of students do have difficulties in mathematics right from the primary level. An analysis of the CPE reports shows that a significant number of students at primary level have not acquired conceptual understanding of different mathematical concepts. A study needs to be carried out to identify what difficulties students at primary level experience in mathematics and identify ways of helping them to overcome these difficulties.

Literature review

Learning mathematics with understanding has been the subject of many studies (Treagust, Duit, & Fraser, 1996; Fennema & Romberg, 1999; Jaworski, 2003; Stylianides & Stylianides, 2007). Studies conducted to identify ways and means to help children make sense of mathematics have made several recommendations " *Teach to the developmental characteristics of students, actively involve students, move learning form concrete to abstract and use communication to encourage*

understanding" Reys, Lindquist, Lambdin, & Smitth, 2009, pp. 25-29). It has been argued that *"failure to learn basic mathematical skills can contribute heavily to later learning problems in mathematics. This is due to the systematic, hierarchical nature of mathematics, with higher level skills being dependent on the student's mastery and attainment of proficiency with basic facts*" (Braten & Thronsten, 1998, p. 152). The inability of students with learning difficulties in mathematics to develop and/or use appropriate strategies has also been highlighted by Braten & Thronsten, (1998).

Research (Geary, 2004, cited in Hannell, 2005) has shown that 5-8 % of pupils in a class have dyscalculia. It has also been argued that many pupils with dyscalculia have significant difficulties with the language of mathematics. In fact (Garnett, 1998, cited in Hannell, 2005, p. 6) stipulated that "*Pupils with mathematical difficulties often cannot, or do not, use their own internal language to manage the mathematical tasks they are attempting*". Moreover, it has been found that pupils with dyscalculia frequently have memory deficits. The deficits may be in working memory, short-term memory or long-term memory. Geary, 2004, cited in Hannell, 2005, p. 11) argued that "*Many children with MLD (mathematics learning disabilities) have difficulties in retrieving basic arithmetic facts from long-term memory; a deficit that often does not improve"*. Several characteristics have been identified (Henderson, Came & Bough, 2003; Hannell, 2005) regarding pupils with dyscalculia. They are slow as compared to offers in the class. They tend to rely on tangible counting supports such as fingers or tally marks. They refrain from asking questions or participating in discussions. They have difficulties in remembering basic mathematical facts. They tend to rely on imitation and rote learning instead of understanding. They can 'do' sums mechanically but cannot explain the process.

They have difficulties in understanding the language of mathematics and experience difficulties transferring from the concrete to abstract thinking. They also have difficulties making connections between the pictorial representations for a numerical value.

Several studies have provided support for schema based word problem solving instruction that emphasizes conceptual understanding (Jitendra & DiPipi, 2002, 2003). Other studies advocated the use of meta-cognitive strategies to help children with learning difficulties. In fact they (Kirk et al. 2006, cited in Woolfolk, Hughes & Walkup, 2008, p. 320) noted that " *For learners with*

learning difficulties, executive control processes (that is, meta-cognitive strategies) such as planning, organizing, monitoring progress and making adaptations are essentially important, but often underdeveloped". Research (Ozsoy & Ataman, 2009) has shown that instruction of meta-cognitive strategy has resulted in an increase of problem solving skills of students at primary level. Meta-cognition involves three kinds of knowledge: (1) declarative knowledge: knowing *what* to do, (2) procedural knowledge: knowing *how* to use the strategies, and (3) conditional knowledge: knowing *when* and *why* to apply the procedures and strategies (Bruning et al. 2004, cited in Eggen & Kauchak, 2010). Meta-cognition is the strategic application of this declarative, procedural and conditional knowledge to accomplish goals and solve problems (Schunk, 2004, cited in Eggen & Kauchak, 2010).

Methodology

A case-study approach was adopted for the study. It combines both a quantitative and a qualitative approach. Three primary schools were chosen based on their performance in the CPE examinations. After a few visits to the school to explain the purpose of the study, the Headmaster of each of the three schools was requested to identify one Standard Four class in the school. The classroom teacher of each of the classes was then explained the purpose of the study and was briefed about the training program.

. The marks of the students in each class in their Standard Three examinations were collected from the school management. These were analyzed and the mean and standard deviation of the marks for each class was calculated. The students who scored below one standard deviation from the mean for each class were considered as those having learning difficulties in their learning and were included in the sample. Once the list of students was prepared, it was shown to the classroom teacher who confirmed that these students were indeed encountering problems in the learning of mathematics. There was one classroom teacher who suggested two more names to be added to the sample as they also were lagging behind in their studies. I did not consider them as they were not satisfying the selection criteria of having scored below one standard deviation from the mean. Consequently there were 16 children in all in the whole sample.

The pre-test and the post-test

A questionnaire was designed based on concepts of mathematics up to Standard III and was used as a pre-test. The questionnaire was designed to include basic concepts in mathematics at that level together with word problems that a learner at that level is supposed to deal with. The purpose was to find out to what extent the children have mastered these concepts and what types of mistakes the children commit. It should be noted that the pre-test was administered to all the children in each of the three Standard Four classes. The questionnaire consisted of 12 questions as follows:

Table 3.a Questions

Question	*Underlying mathematical Concept*
1	Interpretation of a picture abacus
2	Writing number in words
3	Addition - Without carrying - With carrying
4	Subtraction - Without borrowing - With borrowing
5	Word problem on addition of numbers
6	Word problem on subtraction of volumes
7	Word problem on addition of masses
8	Word problem on multiplication related to volumes
9	Word problem on subtraction related to length
10	Word problem on division of numbers
11	Word problem on subtraction related to money
12	Word problem related to charts

The framework mentioned in Ansell & Pagliaro (2006) was used in designing the word problems. A post-test similar to the pre-test was also designed. Once the pre-test was administered in each of the three Standard Four classes, training sessions were conducted in each school to empower them with strategies for solving a word problem. A strategy called The Make My Maths Easy (M^3E) Strategy was developed to solve mathematical problems which combine both cognitive and meta-cognitive elements based on the one proposed by Montague (1992) (cited in Wright, 2011)

Table 3.b Cognitive strategy and meta-cognitive prompts

Cognitive strategy	*Meta-cognitive Sample Prompts*
1. **R**ead the problem The student needs to read the problem and study it carefully. S/he can use the following prompts to check whether this is properly done	**Say**: "I will read the problem. I will reread the problem if I don't understand" **Ask**: " Have I read it thoroughly?" Have I highlighted the key words?" **Check**: " I have highlighted the key words and will move forward".
2. **U**nderstand the problem The student needs to understand the problem fully: what have been given, what has been asked?	**Say**: "I need to understand the problem" **Ask**: " Do I fully understand it?" **Check**: "Now that I understand the problem, I move forward"
3. **S**ay the problem in your words The student needs to restate the problem in your own words.	**Say**: "I will restate the problem in my own words" **Ask**: " Have I used all the highlighted key words while re-stating the problem in my own words" **Check**: "I have re-stated the problem in my own words that will help me solve it
4. **P**lan a solution The student needs to plan to solve the problem	**Say:** " I will make a plan to solve the problem" **Ask**: "What is the first step of this plan? What is the next step?" **Check**: " I have designed a plan with the right steps to solve the problem"
5. **E**xecute the plan The student needs to follow the plan to find the solution to the problem.	**Say**: " I will complete the answer the problem" **Ask**: "Does my answer sound right?" **Check**: " I carried out all the steps of the plan in the correct order"
6. **C**heck the answer	**Say**: " I will check all the steps of my answer"

The student needs to review the computation steps to verify the answer. S/he needs also to assess whether the answer is logically acceptable.	**Ask**: " Did I go through each step in my answer and checked the work?" **Check**: " I am satisfied with my answer"

The students were trained in how to use this strategy in 13 sessions (each of 30 minutes) in the three schools.

The post-test was then administered to the students in the sample following the training sessions. Data obtained from the pre-test and post-test were analyzed using appropriated statistics and these will be discussed at a later stage. Two students together with their parents were interviewed to probe further on the effectiveness of the strategy training program.

Findings

The table below shows the total score of each of the 16 children n the sample in the pre-test and the post-test.

Table 4. Total score of the students in the sample in both pre-test and post-test

Student	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	10	11	**12**	**13**	**14**	**15**	**16**
Pre-test	12	2	12	7	6	7	8	3	1	11	1	7	6	10	7	2
Post-test	11	13	18	7	7	20	9	12	3	12	2	9	14	14	21	10

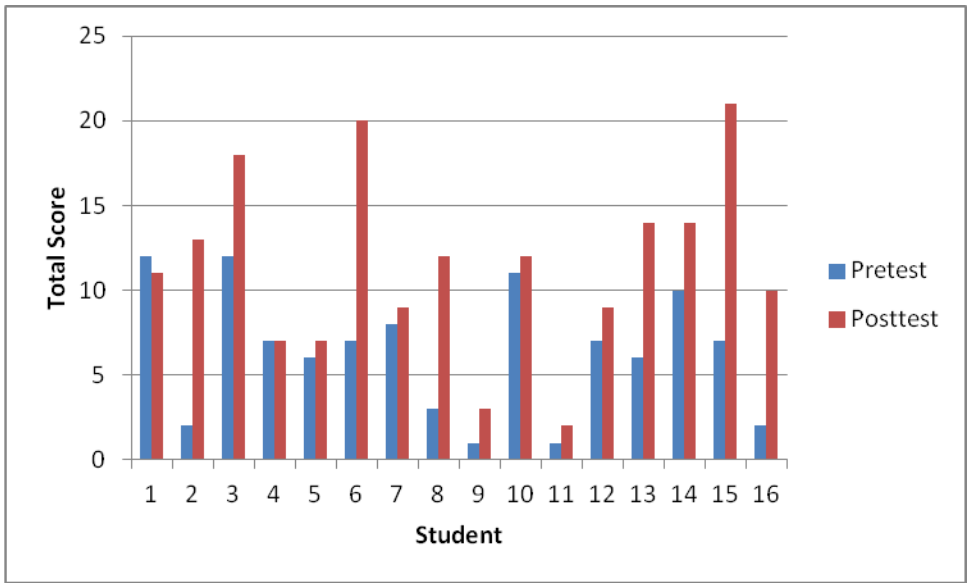

Fig. 1: Bar Chart for the total scores in pre-test and post-test

It was found that the students have performed better in the post-test as compared to the pre-test. To perform statistical analysis, a test of normality (Shopiro-Wilk test) was carried out for the scores of pre-test and post-test and both were found to be normal (p-value of 0.162447 and 0.82166 for pre-test and post-test respectively, both > 0.05). Thus, paired t-test was found to be appropriate.

The following data were obtained from the scores for pre-test and post-test:

Table 5. Results of the pre and post test

Pre-test	**Post-test**
Mean= 6.375	Mean = 11.375
Standard Deviation = 3.739	Standard Deviation = 5.402
n = 16	n = 16

The following hypothesis test was performed:

H_0 : (no difference in mean mark of pre-test and post-test)

H_1 : (mean mark of pre-test less than mean mark of post-test)

Using a paired t-test, p-value = 0.00049

Since this value is less than 0.05, it can be concluded that there is sufficient evidence at 5% level that the mean performance of the students have increased from the pre-test and the post- test.
This provides evidence that the strategy has been effective in helping the children in their problem solving in mathematics.

Case studies

To probe further, two children in the sample, a boy who has made significant progress from the pre-test to the post-test and a girl who did not show any significant improvement in her performance, were interviewed. The parents also were interviewed to find out background information on the children.

Case study one

Student 1 is a boy, 8 years old, who resides at Residence Kennedy, Quatre Bornes. He lives with his family which comprises of his father (42 years old), mother (38 years old), his 3 sisters and 3 brothers. He is 5th in his family. His father is unemployed and had undergone a surgical operation. His mother is a housemaid and she is the only one working in the family. Child 1 has three sisters and two brothers in secondary schools and one sister who has recently taken part in the CPE examinations and is awaiting results. The family is very modest and all the children have to be involved in helping the parents in their household work. The region where he resides can be described to be a deprived one. There is high rate of unemployment and a lot of cases of broken families. Drugs, alcohol and prostitution are very much present in this region. Child 1 was born through normally delivery and attended pre-primary school for two years before joining the primary school in the region. The school is a ZEP school as its performance at CPE level is below 40% for the past 15 years. The father described Child 1 to be having problems with studies since he joined the primary school. He has always been lagging behind and rarely studies at home after school. He spends most of his spare time playing football on the ground which is just next to their house. The teacher also described child 1 as playful and not interested in studies.

During the training sessions we could notice Child 1 developing a liking for mathematics and participating in the classroom discussion. At first he was having problems with basic concepts in

mathematics, for instance number names of one digit number, basic additions and subtraction facts and language problems. He showed interest during the training sessions and was learning the number names. During the training sessions he was using his fingers to add or subtract two numbers. His performance in the pre-test and post-test question-wise is shown in the Table 6 below:

Table 6. Performance of Child 1 in the two test

Q	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Total
Pre-test	1	0	1	0	0	0	0	0	0	0	0	0	2
Post-test	1	1	2	1	3	0	1	0	2	0	0	2	11

Q=question

A graphical representation of the same data is shown below.

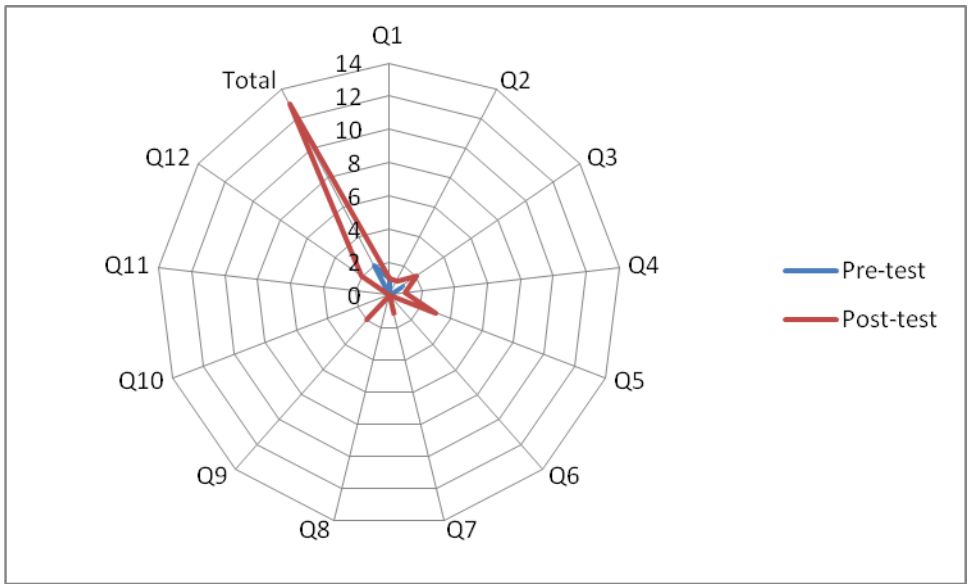

Figure 2. Graphical representation of pre- and post test results of Child 1

One can note that, in spite of his background at home which does not provide enough support to his education, Child 1 has made significant progress form the pre-test to the post-test. During the interview he did acknowledge that the training sessions have been beneficial to him. Close monitoring of his work and corrective feedback have helped him develop a liking for mathematics.

Case study two

Child 2 is a girl, 8 years old, who resides at Palma Road, Quatre Bornes. She lives with his family which comprises of his father and his grandmother. The parents are divorced since she was three and a half years old. The father is a machine operator in a private company and works till late often. Consequently she stays with her grandmother for most of the time. She attended pre-primary school since she was two and a half years old. She has been described by her dad as being very studious but she was three and a half years old her parents divorced. Since then she has been performing badly in her studies. She then joined the primary school in her locality and

she has been lagging behind in her studies. She spends most of her time playing with her friends in the neighborhood. The father said that the few occasions he has to make study at home he has found that she forgets things very often. For instance she does not remember her multiplication tables in mathematics. Child 2 described mathematics as being a difficult subject and the subjects she likes most are English and French.

During the training sessions, Child 2 has been found to be very participative but answers questions too fast without giving herself time to think and reflect. She is very popular among her friends and likes to help them often. She declared to have found the RUSPEC strategy very helpful, however her performance in the post-test has not improved significantly. His performance in the pre-test and post-test question-wise is shown in the Table 7.

Table 7. Performance of Child 2 in the pre- and post-tests

Question	Q1	Q2	Q3	Q4	Q5		Q7	Q8	Q9	Q10	Q11	Q12	Total
Pre-test	1	0	1	0	3		0	0	0	0	0	1	6
Post-test	1	0	0	1	3		1	0	0	0	0	0	7

A graphical representation of the same data is shown below.

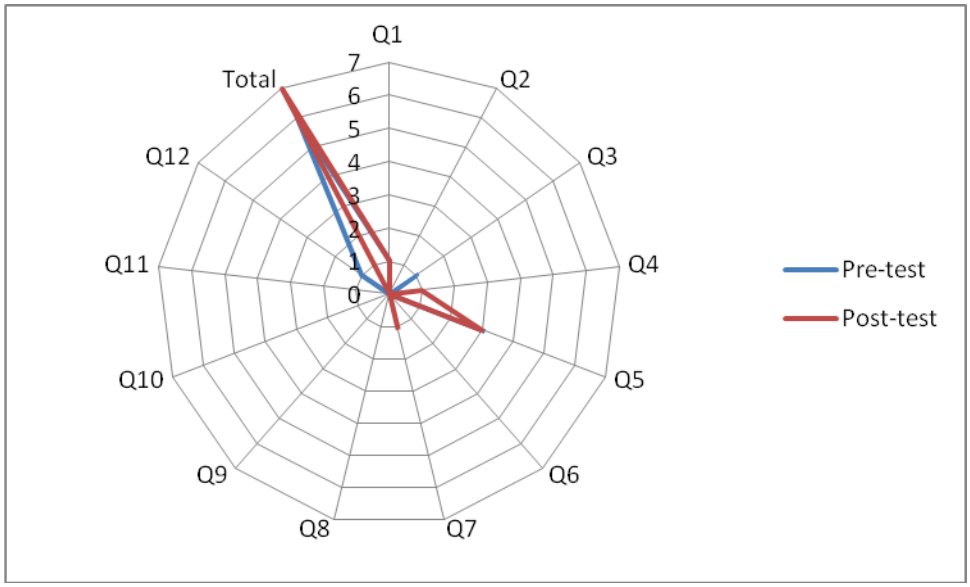

Figure 3. Graphical representation of the performance of Child 2 in the pre- and post tests

It can be noted that this child has not made any significant progress. During the training sessions she was found to be still having problems with the basic concepts in mathematics. However, she was one of the students in the sample who has been volunteering the most to answer questions. She likes to answer questions, help her friends but does not take enough time to think and process the question that has been asked before answering.

Main Findings

One of the main outcomes of the study is the lack of conceptual understanding in mathematics at the primary level. This is in line with a study conducted in Mauritius at the secondary level (Bessoondyal, 2008). During the present study, one could find children who could do calculations in mathematics at the primary level but they could not explain the process. They had heavy reliance on concrete objects to perform addition and subtraction. This is in keeping with studies conducted by Henderson, Came & Bough (2003) and Hannell (2005). Non-mastery of basic mathematical concepts have been found to be detrimental to the formation of further mathematical concepts because of the hierarchical nature of mathematics, as noted by Braten & Thronsten (1998). Through discussions with the children involved in the training program, it was found that one of the major causes of their difficulties in learning mathematics is the perception of mathematics as a difficult subject, in line with research conducted by Mundia (2012). Repetitive failure in lower classes resulted in the development of a negative attitude towards

mathematics and the perception that mathematics is a difficult subject. Memory was also found to be an area of concern for children with learning difficulties, as pointed out by Dowker (2004). They cannot remember basic mathematical facts and have to resort to counting on fingers or using tally marks to do a simple sum like, say 3 + 5, in line with research conducted by Hannell (2005). Many of the characteristics described by Hannell (2005) for children with dyscalculia were found to be present among many children in the sample, some of which are: being slow in the class, having problems copying work from whiteboard, unable to explain mathematical processes and not participating in classroom discussions. It should, however, be noted that 3 children in the sample were very enthusiastic in answering questions during the training sessions. Very often they did not wait for the question to be asked completely when they were already responding. While building on this enthusiasm to participate, they were encouraged to listen to the complete question, think and then answer.

Another major outcome of this study is the difficulties children encounter with problem solving, in line with research conducted by Gooding (2009). Understanding the word problem itself has been found to be a major obstacle. Children were found to be operating with some verbal cues and tend to jump to a mathematical operation to be used, without proper analysis of the question. For instance, in response to a question like "*Ali has 18 marbles. Rita has 13 marbles. How many more marbles does Ali have than Rita?*", there were some children who used the mathematical operation ADDITION because of the word ***MORE.*** Children tend to be operating with a set of associations, which they have created. Moreover, there were instances when children, who at first could not solve a problem set in English, could do so when the problem was translated in Creole (a local dialect).

Another major finding of this study is the efficiency of a strategy training program in helping children in their learning of mathematics, in line with research conducted by Johnson (1998). Together with statistical analysis conducted on data obtained from pre-test and post-test, the motivation and participation of the children in the sample did show that strategy training does help in enhancing learning of mathematics. Use of meta-cognitive strategies was found to be useful in solving word problems in mathematics, in keeping with studies conducted by Ozsoy & Ataman (2009) and Eggen & Kauchak (2010).

Conclusion

This study has shown that children at the primary level in Mauritius do encounter difficulties with conceptual understanding of mathematical concepts. Furthermore, in line with research, there are children with learning difficulties in mathematics in our mainstream classes. This study has revealed that the difficulties can go down to very basic concepts of even Standard I and these children are at present in Standard IV. This can be said to be as a result of 'automatic promotion' at the primary level in Mauritius. This study has shown that these children are facing a number of problems ranging from memory deficits, language of mathematics, perception of mathematics as a difficult subject, repeated failure and low self-esteem. If the needs of these children are not catered for, their negative experiences with mathematics will continue with the children developing a negative attitude towards mathematics which further affects their performance in the subject. With the international concern and the commitment of our country for the education of ALL children, opportunities need to be provided so that these children too can succeed in their schooling and consequently in life.

In this study a strategy training program was conducted with a sample of children of Standard IV who were having learning difficulties in mathematics. They were empowered with strategies which combined both cognitive and meta-cognitive elements to solve word problems in mathematics. Data obtained from this study provided evidence of the effectiveness of this strategy training in helping those children in solving word problems in mathematics. It has also helped the children experience success in mathematical activities and develop a positive attitude towards mathematics. We, all stakeholders, need to continue on this right path and provide further support to these children to enable them to succeed in the schooling system and in life.

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