AN ANALYSIS OF WORD PROBLEMS IN SCHOOL MATHEMATICS TEXTS: OPERATION OF ADDITION AND SUBTRACTION

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This paper discusses the types of word problems represented in Malaysia's primary one, primary two and primary three mathematics texts based on Van De Walle's model (1998) in the operations of addition and subtraction. A test was constructed to measure students' success based on this model. The data from this study indicates that the Malaysian mathematics texts used in primary one, primary two and primary three do not represent the distribution of this classification in a systematic manner. There is an over emphasis on certain categories while some of the categories are minimally represented and one category has no representation at all. The data from the achievement test indicates generally that children across the grades obtained lower scores on word problems that were under represented in the mathematics texts.

Introduction

In Malaysia, textbooks play an important role as a tool in the teaching and learning process because of their close relationship with classroom instruction. It is structured in a way for students and teachers to follow with suitable concepts presentation, activities and exercises. In Malaysia, textbooks are important tools especially for teachers in organizing their scheme of work for their classes. In the Malaysian Education System, the textbooks are written by experienced teachers, lecturers and educators under the tutelage of the Curriculum Development Center (CDC). The CDC prepares the syllabus for writers to write a book, strictly adhering to the guidelines and specification as laid out by the CDC. All students are required to have textbooks for their learning process and one can say in short that the textbook is the main resource for both teachers and students in their teaching and learning process.

The difference between textbooks and revision books widely available commercially in the Malaysian market lies mainly in the approach that the books adopt in the learning process. The former stresses concept development, which then evolves into activities and exercises while the latter emphasizes the application of concepts. In Malaysia it is felt that mathematics textbooks have an important role to play as the subject deals with various and fundamental concepts that need to be understood before children can apply them in problem solving situations.

Improving children's word problem skills is an important aim in mathematics education. While solving problems, children not only use their mathematical concepts and knowledge already constructed (Wyndham, 1997) but also improve their knowledge and understanding thus leading them to a better mathematical insight. Therefore, word problems as a form of problem solving should be used as the basis for teaching mathematical concepts so that children construct their own knowledge (Peterson, Fennema & Carpenter, 1989). In this sense, carefully chosen word problems can provide a rich context for learning addition and subtraction (Greer, 1997).

One of the studies on the use and influence of textbooks in classrooms was conducted by Stodolsky (1989). She proposed that the use and influence of textbooks should be analyzed with respect to topics, content and its comparison with the literature of a similar topic. Both textbooks and word problems occupy an important position in the teaching and learning process and as Ball and Cohen

(1996) pointed out"… curriculum materials could contribute to professional practice if they were created with closer attention to processes of curriculum enactment" (p. 7). This paper basically examines the relationship between the curriculum materials specifications that adhere to the syllabus laid by CDC, on types of problems in addition and subtraction and the curriculum specifications available in the literature based on research. The author believes that the interaction between curriculum materials in textbooks and the specifications in the research literature is a relatively unexplored field in curriculum studies in Malaysia.

Background

Research (Clements, 1999; Parmjit's 2003; Vergnaud, 1988) has shown that children in early grades faced great difficulty in solving word problems as compared to computational problems in mathematics. It is not enough to teach the computation of 5 x 5 = 25. It has to be realized that there are practical applications and ramifications, which will continue to be useful throughout the student's life. These applications are usually assessed through word problems and students should be exposed to the various types of problems. As Baldino (2001) stated, students find it difficult to adjust to word problems because they are not properly "trained" to deal with them. If that is so, then these students should be exposed to the various types of word problems to acquaint them with problem solving techniques and the associated arithmetical computations.

In a mathematics curriculum, there are differences between exercises and problems. Exercises are tasks for which students learn appropriate solution procedures, but have yet to become adept at applying these procedures or at matching these procedures to appropriate problems. Exercises may be hard or easy, but they are never puzzling, for it is always immediately clear how to proceed and solve a problem algorithmically by recognition, recall and reproduction. The selection of appropriate algorithms and their modification to accommodate the unique aspects of a problem are important in problem solving. Thus algorithms have sometimes been defined as "black boxes used to produce answers" with little or no understanding (Lockhead & Collura, 1981, p. 47).

In contrast, true problem solving is a more difficult and complete task that requires analysis and reasoning toward a goal (or solution) based on an understanding of the domain from which the task is drawn (Smith, 1991). It requires more than just simple recognition or recall from memory. Problems cannot be solved algorithmically with little or no understanding of what has been done or why it is correct. In making this distinction, the task of problem solving requires analysis and reasoning that must be based on an understanding of the content involved. The author believes that much of the current classroom mathematics syllabi involve tasks that would be considered "exercises", not true problems. Often Malaysian students are only asked to apply procedures or match procedures to appropriate problems (Munirah, 2005).

In view of the difficulty faced by children in mathematical problem solving, is it possible that the texts used in school are not sufficient in dealing with the various types of problems tested? In this paper, mathematics texts in Malaysia for primary one, primary two and primary three are the elements chosen to be analyzed using the Van de Walle's (1998) model to view how far the school texts emphasize word problems and their corresponding curriculum literature with regard to the topic of addition and subtraction in word problems.

Beginning 2003, there was a call for a change in the medium of instruction in Mathematics from Bahasa Malaysia (the official language in Malaysia) to English which is taught as a second language. The change in the medium of instruction for the teaching of Mathematics and Science is an important educational landmark in Malaysia. Today the programme is called the Teaching and Learning of Science and Mathematics in English or PPSMI (*Pengajaran dan Pembelajaran Sains dan Matematik dalam Bahasa Inggeris*). With English being taught as a second language, the issue of limited English proficiency of both students and teachers has become an issue confronting the ministry. Nevertheless steps have been taken to ensure the transition will not be a painful one for all the stakeholders concerned (Gurnam, 2005).

The purpose of this study is threefold: First, it examines whether primary school mathematics textbooks adequately include the standard word problems representing different meanings of addition and subtraction. Secondly, it seeks to determine students' success on the predetermined eleven types of problems and third, it looks for any relationship between the two: textbook inclusion of problem type and student success on that problem type.

Method

Two of the Malaysian Mathematics textbooks, approved by the Education Ministry, used in primary one and primary two were selected to be analyzed to achieve the first purpose of this study. The eleven types of standard word problems as shown in Table 1, modeled from Van De Walle (1998), was the benchmark in analyzing the category as given. The researcher independently categorized each problem in the textbooks in accordance with the given categories. All word problems that can be solved using addition and subtraction of natural numbers were included while symbolic expressions such as "12 + 23 = ?" and phrases such as "4 more than 10?" were excluded.

In order to achieve the second purpose, one hundred eighty six primary school students ranging from primary one to primary three, in which 48 were from primary one, 65 from primary two and 73 from primary three, participated in this study. These students were selected from the top classes for each of the respective grades. The objective of selecting these students was to measure their understanding of word problems based on the eleven types mentioned earlier. To quantify this outcome, an instrument was constructed in which the problems were adapted from the eleven types of standard word problems (Peterson, et al., 1989) using Van De Walle's (1998) model. English language has been the medium of instruction for the teaching of mathematics for these students since 2003 and in view of this, the problems assigned in the test was in the English language. The eleven categories are illustrated in Table 1. There were eleven problems in this instrument with representation from each category. A numerical value was assigned to each of these criterion and students' responses were categorized on a 3-point scale based on the responses. The 3-point scale used was:

2- All correct,
1-Small / careless error(s),
0-Unlikely to lead to a solution.

Table 1
Categorization of Standard Addition and Subtraction Problems

Category	Information	Category	Information
1. JRU	Join Result Unknown	7. CDU	Compare Difference Unknown
2. JCU	Join Change Unknown	8. CLU	Compare Larger Unknown
3. JIU	Join Initial Unknown	9. CSU	Compare Smaller Unknown
4. SRU	Separate Result Unknown	10. PWU	Part-whole Whole Unknown
5. SCU	Separate Change Unknown	11. PPU	Part-whole Part Unknown
6. SIU	Separate Initial Unknown		

Table 2
Categorization and Problems Using Van De Walle's (1998) Model

Category	Problem
1. JRU	Adam has 5 marbles. Ahmad gives him 3 more marbles. How many marbles does Adam have altogether?
2. JCU	Adam had 5 marbles. Ahmad gave him some more marbles. Now Adam has 8 marbles. How many did Ahmad give him?
3. JIU	Adam has some marbles. Ahmad gives him 3 more. Now Adam has 8 marbles. How many marbles did Adam have at first (to begin with)?
4. SRU	Adam has 8 marbles. He gives 3 marbles to Ahmad. How many marbles does Adam have now?
5. SCU	Adam had 8 marbles. He gave some to Ahmad. Now Adam has 5 marbles left. How many did he give to Ahmad?
6. SIU	Adam had some marbles. He gave 3 marbles to Ahmad. Now Adam has 5 marbles left. How many marbles did Adam have at first to begin with?
7. CDU	Adam has 8 marbles and Ahmad has 5 marbles. How many more marbles does Adam have than Ahmad?
8. CLU	Adam has 3 more marbles than Ahmad. Ahmad has 5 marbles. How many marbles does Adam have?
9. CSU	Ahmad has 3 fewer marbles than Adam. Adam has 8 marbles. How many marbles does Ahmad have?
10. PWU	Adam has 5 blue and 3 red marbles. How many marbles does he have altogether?
11. PPU	Adam has 8 marbles. 5 of them are red, and the rest are blue. How many blue marbles does Adam have?

To achieve the third purpose, a correlation statistical analysis was applied to determine the relationship between the distribution of the eleven categories of problem types in school texts and student success with these problems.

Results

The following four sub-sections present the findings of this study. These are: (1) the distribution of word problems in texts over grades, (2) the distribution of word problems in texts in accordance with the eleven categories using Van De Walle's (1998) model, (3) students success in the eleven-type problem categories, and (4) the relationship between the distribution of word problems in texts and students' success with problem types.

The Distribution of Word Problems in Texts over Grades

The Malaysian mathematics school texts for primary one and primary two are namely the textbook and the activity book. The focus of each of these texts differs where the former lays emphasis on concept construction and the latter concentrates on supplementary exercises to enhance understanding. Each of these texts is divided into two parts, namely Part 1 and Part 2. The primary one textbook consists of 11 units of study while the primary two textbooks consist of 18 units, which are divided into the two parts for each grade. From the analysis conducted as shown in Table 3, there are a total of 92 word problems in the primary 1 textbook, 120 word problems in Primary 2 textbook and 22 in primary 3 textbook used.

Table 3
Word Problems in Texts (Textbook and Activity Book)

	Text Book		Activity Book		
Grades	Part 1	Part 2	Part 1	Part 2	Total
Primary 1	15	19	34	24	92
Primary 2	31	22	36	31	120
Primary 3*	22		No Activity Book		22

Note: Year 3 analysis is based on the old text book without an activity book

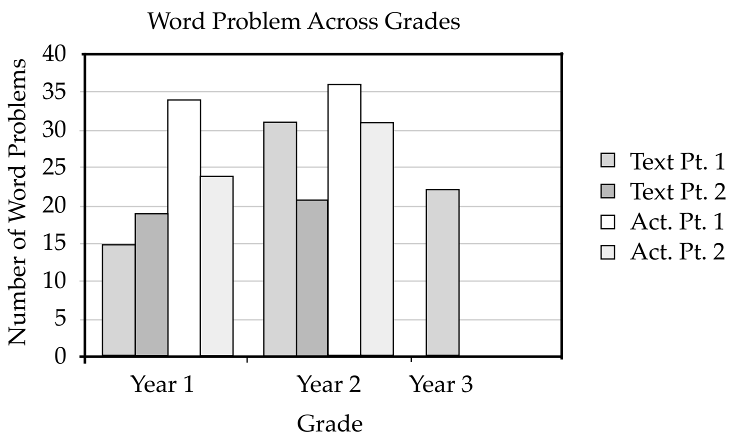

Figure 1. Distribution of word problems over grades.

The Distribution of Word Problems in Textbooks in Accordance with the Eleven Categories

All the addition and subtraction word problems were categorized into eleven categories based on Van De Walle's Model. Figure 2, Figure 3 and Figure 4 represent the distribution of word problems in the textbooks for each of the grades in the various categories. This distribution represents the total word problems from the textbook and the activity book. It was expected that there should be an even spread across the eleven categories. However, as presented in Figure 2 and Figure 3, the first and fourth categories were over represented in both the primary 1 and primary 2 school mathematics texts. Similarly, the tenth category was the second most frequently used problem type in both the textbooks. Category 9 was not represented at all in both grades while category 3 did not have any representation in Primary 2. Other categories, the 2^{nd}, 5^{th}, 6^{th}, 7^{th}, and 8^{th} categories were not adequately represented in both Primary 1 and Primary 2 texts.

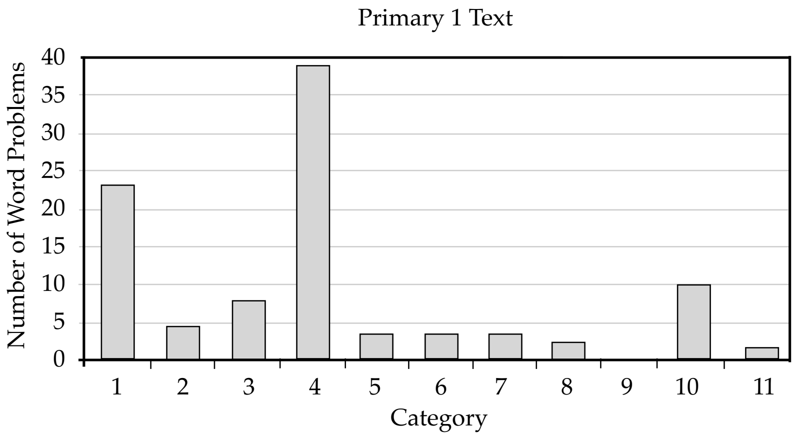

Figure 2: Distribution of word problems in Primary One textbook.

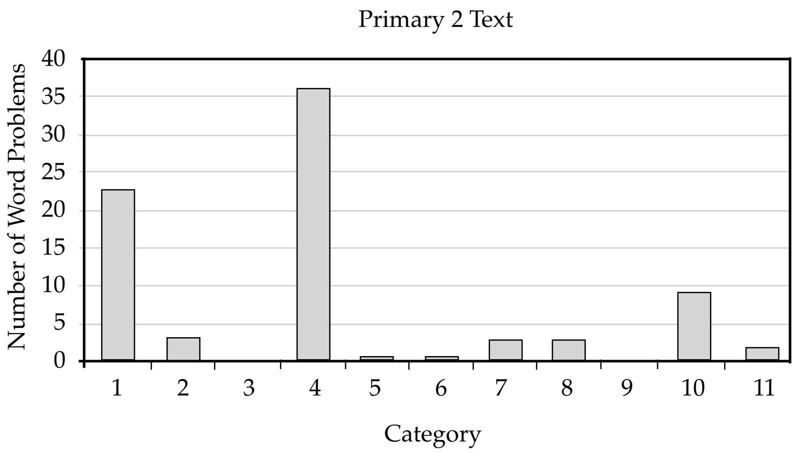

Figure 3: Distribution of word problems in Primary Two textbook.

Similarly, the Primary Three textbooks also emphasize on problem types in categories 1, 4 and 10. There is some representation in categories 1, 6, 7, 8, 11. However, there were no problem types in categories 2, 3, 5 and 9. Again, as in the Primary One and Primary Two textbooks, there is an inadequate representation of the types of problems in these textbooks. Table 4 indicates the number of word problems in Primary One and Primary Two texts, which include both the textbook and the activity book. The Primary Three textbook as shown in the table is for comparison purposes only and is not indicated here. This is because it has yet to adhere to the new text that will be out by 2006. The table shows that there are 92 and 120 word problems of addition and subtraction in the mathematics texts for Primary One and Primary Two respectively. There is an increase of 56.5% and 15.5 % respectively in the number of word problems in the textbooks and the activity books. Overall, there is an increase of 30.4% in the number of word problems from the Primary One texts to the Primary Two texts.

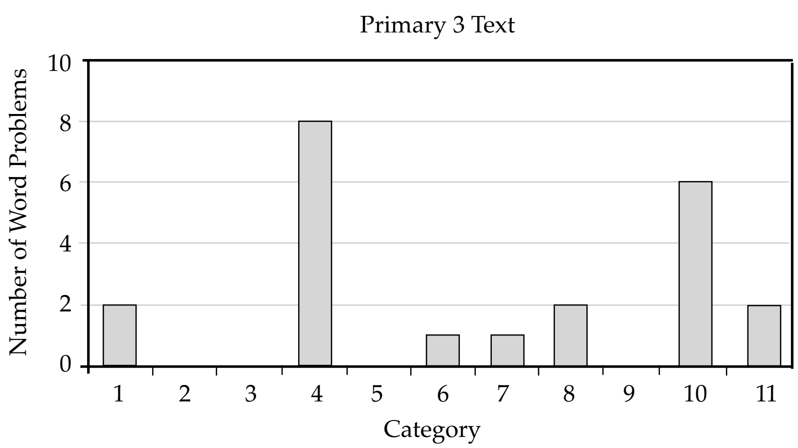

Figure 4. Distribution of word problems in Primary Three text.

Table 4
Distribution of Word Problems Categories in Primary One, Primary Two and Primary Three Texts

Category	Mathematics School Text Book & Activity Book							Total
	Primary 1			Primary 2			Primary 3	
	Text	Activity	Total (%)	Text	Activity	Total (%)	Text	(%)
1	12	10	22 (24%)	4	31	35 (29%)	2	59 (25.2%)
2	1	3	4 (4.3%)	2	3	5 (4.2%)	-	9 (3.8%)
3	2	5	7 (7.5%)	-	-	0 (0%)	-	7 (3%)
4	13	24	37 (40%)	30	25	55 (46%)	8	100 (43%)
5	1	2	3 (3.3%)	-	1	1 (0.8%)	-	4 (1.7%)
6	1	2	3 (3.3%)	-	1	1 (0.8%)	1	5 (2.2%)
7	1	2	3 (3.3%)	3	-	3 (2.5%)	1	7 (3%)
8	1	1	2 (2.2%)	2	2	4 (3.3%)	2	8 (3.4%)
9	-	-	0 (0%)	-	-	0 (0%)	-	0 (0%)
10	2	8	10 (11%)	11	3	14 (11.7%)	6	30 (12.8%)
11	-	1	1 (1.1%)	1	1	2 (1.7%)	2	5 (2.1%)
Total	34	58	92 (100%)	53	67	120 (100%)	22	234 (100%)

In summing up Table 4 on the representation of word problems, a chart representing the total number of problems across the eleven categories is shown in Figure 5. It indicates that category 1, category 4 and category 10 are the types of problems being emphasized in the Malaysian school texts for early primary and there is an inadequate representation of the other categories. Surprisingly, there was no representation of category 9 problems in these texts.

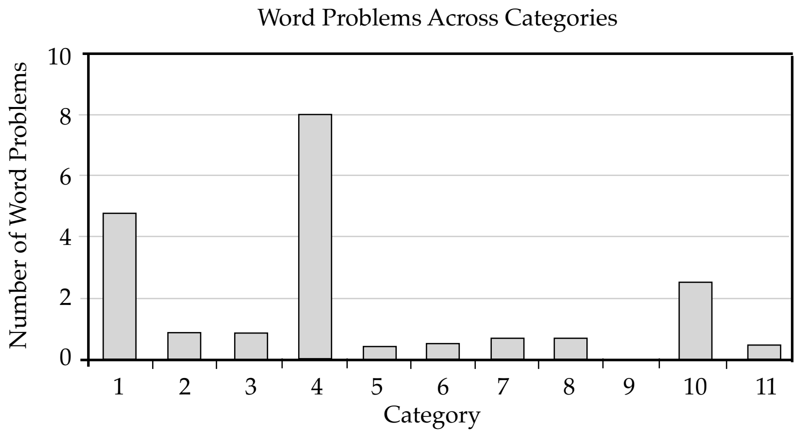

Figure 5. Distribution of word problems across categories.

Students' Success in the Eleven Word Problem Categories

Students' success in the eleven categories of problems is shown in Figure 6. As indicated, it ranged from 12.5 % to 98 % for the various categories with the average lowest in category 7, category 9 and category 11. Generally, Primary Three students were more successful than Primary Two and Primary One students in all the categories of word problems except in category 6 and category 8.

The variation in student's success, especially Primary Two and Primary Three, according to the categories followed almost the same pattern where the success of Primary One students fluctuated and did not seem to be in tandem with Primary Two and Primary Three students.

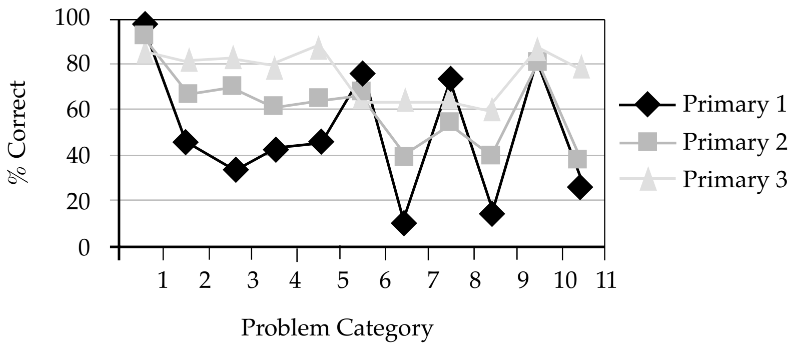

Figure 6. Students' success in the eleven categories of problems.

Table 5
Students' Success in Categories Above 60%

Level	Successful	Unsuccessful
Primary One	1, 6, 8, 10 (65%)	2, 3, 4, 5, 6, 7, 9, 11
Primary Two	1, 2, 3, 4, 5, 6, 10	4, 5, 7, 8, 9, 11

Table 5 indicates students' success of above 60% in the eleven categories. As stated earlier, these students were selected from the top classes for each of the respective grades and as being "brighter students" they should have the experience in dealing with these problems. However, the table shows that students in both Primary One and Primary Two faced a common difficulty of success of less than 60% in category 4, 5, 7, 9 and 11.

The Relationship Between the Distributions of Word Problems in Textbooks and the Students' Success in Problem Types

To determine if any significant relationship exists between the distribution of word problems and students achievement on the 11 types of word problems, a correlation statistical analysis using Pearson R was used. The correlation between the distribution of word problems and students success was significant at 0.05 level with r = 0.5988, p = 0.043, n = 48 and r = 0.623, p = 0.035, n = 65 for both Primary One and Primary Two respectively. These values indicate a moderate relationship between the distribution of word problems and students success in the problems types for both Primary One and Primary Two.

Students' Achievement in the Word Problem Test Across Grades

Table 6 indicates the mean score obtained by the students across the three grades.

Table 6
Comparison of mean score across grades

Grade	N	Mean (Max Score: 22)	Std. Dev
Primary One	48	10.8	4.4
Primary Two	65	13.1	4.8
Primary Three	73	16.4	4.8

The mean score, 16.4 obtained by Primary Three students is the highest followed by 13.1 and 10.8 as obtained by Primary Two and Primary One students respectively. The maximum score for the test was 22. In view of this, it could be said that these students' performance was not on par as expected in their respective grades, especially for students who were selected from the better classes for each grade.

Discussion and Conclusion

This paper embarked on a three-fold journey. First, it was to analyse the distribution of word problems in Primary One, Primary Two and, to a certain extent Primary Three, mathematics texts based on Van De Walle's (1998) model in the operation of addition and subtraction. Secondly, it examined students achievement in the eleven categories based in the said model and thirdly, it examined the relationship between the distribution of the problems and students success in the eleven categories.

The data from the analysis of school mathematics texts indicated that the Malaysian mathematics texts used in Primary One, Primary Two and Primary Three do not adequately represent the distribution of this classification based on Van De Walle's model. The bulk of the word problems distribution in these texts was based on category 1 (25.2%), category 4 (43%) and category 10 (12.8%) compared to the other categories across the grades which has a representation of less than 4%. The over representation of category 1 and category 4, and to a lesser extent category 10 with no representation at all in category 9, may prevent students from developing a rich concept of addition and subtraction or be "additive" thinkers which might eventually hinder the development of children's problems solving skills. It is not enough to teach the computation of $5 + 3 = 8$; it has to be realized that there are practical applications and ramifications, which will continue to be useful throughout the student's life. These applications are usually assessed through word problems and students should be exposed to the various types of problems in order for them to be problem solvers.

The results from the test based on the eleven categories indicate that these students were not able to cope with word problems, especially those that were under represented in the mathematics texts. Students obtained the lowest score for category 7 (12.5%, 40%, 64.4% respectively) and category 9 (16.7%, 40%, 61.6 % respectively) across the three grades (Figure 6). According to the Malaysian Syllabus for mathematics, students in Primary Two and Primary Three are required to do addition and subtraction with three to four digit numbers. Even though the sum of the numbers used in the problems was less than 20, the success rate was as low as 40%. Furthermore it must be noted that the students in this study were selected from the top classes for each of the respective grades and should have the experience in dealing with these concepts. If these students faced difficulty in solving the given problems, what about the other students at large? Is this difficulty due to the lack of familiarity with these problems? Students in this study obtained low scores on the categories of word problems that were under represented in the mathematics texts. However, this relationship could be incidental and further investigation especially qualitative research is needed in order to reach a reliable conclusion.

Some might argue that the questions based on the eleven types of problems given in the test are mainly due to the ways in which the problems are presented. They might argue that the problems are twisted in ways that confuse students. For example:

Category 7: Adam has 8 marbles and Ahmad has 5 marbles. How many more marbles does Adam have than Ahmad?

Category 9: Ahmad has 3 fewer marbles than Adam. Adam has 8 marbles. How many marbles does Ahmad have?

However, from an educational perspective, for a student to be able to get the right answer to a question that is worded in the "right" way that is familiar to the students is just meaningless. Problems in real-world contexts are presented in many forms and word problems come with a range of linguistic structures (Riley, Greeno & Heller, 1983). As mathematics educators, we should assist them to respond appropriately to questions incorporating the full range of linguistic structures commonly used in day-by day discourse. Thus, if the wording of an English language mathematics word problem is grammatically correct and is such that normal speakers of English would comprehend its meaning, then it is reasonable to expect students to grasp its meaning.

The topics of addition and subtraction play an important role in the early learning of mathematics in school and one could say that the lack of understanding of these two constructs, as this research suggests, seems to be the critical factor in these children's learning. All over the world, for as long as young children have been expected to learn mathematics in school, they have struggled with mathematics word problems (Ellerton & Clements, 1991). Research findings (Parmjit, 2003; Parmjit's 2004; Mulligan & Mitchelmore, 1997) indicate that children face difficulty in solving word problems and they tend to mix up addition and subtraction operations and to memorize them in isolation. When children memorize without understanding, they may confuse methods or forget steps (Kamii & Dominick 1998). Clements (1999) pointed out that primary-level pupils who attempt to solve mathematics word problems often have difficulties at the "comprehension" and "transformation" stages (Newman, 1983). That is to say, they struggle to comprehend the meaning of the question, and if they manage to do that, they often fail to identify sequences of the operations that can be used to solve given word problems.

At this juncture one needs to ask a pertinent question: What happens when students with limited English proficiency are required to learn content subjects like mathematics in English? Today, mathematics students in Malaysia have to learn to grapple with two important issues at hand – learning Mathematics concepts and learning the language. Research (Clements, 1999; Ellerton & Clements, 1991) has shown that semantic and syntactic characteristics of word problems influence problem difficulties. Is it possible that these semantic and syntactic structures are the root of difficulties for these students in dealing with these different categories of word problems? This limited linguistic proficiency of students might be an issue that needs to be investigated.

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