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MAT2013-0815

# A Comparison of the Impact of Natural Language and Manipulatives on Students' Performance on Word Problems

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URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.


ISSN **2241-2891**
22/1/2014

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This paper should be cited as follows:

**Angateeah, K.S., Hurchand, H., Sukon, K.S. and Nunkoo-Gonpot, P.** (2013) **"A Comparison of the Impact of Natural Language and Manipulatives on Students' Performance on Word Problems"** Athens: ATINER'S Conference Paper Series, No: **MAT2013-0815**.

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**Abstract**

Does the use of mother tongue help in learning Mathematics? Who benefits most from it? Can use of manipulatives together with use of mother tongue help to improve knowledge, understanding and performance of learners? In this paper we examine the effect of natural language and of manipulatives on students' performance on word problems in Mathematics at the lower secondary level in Mauritius – an island with multi-ethnic population. An experimental mode of inquiry was used, involving 366 students. A control group (ENG) was established, in which English (L2) was used as the language of instruction. In the first instance, the performance of students in this group was compared to the performance of students in another group (CRE) in which Creole (L1), the mother tongue, was the language of instruction. Then to investigate the effect of manipulatives we extended the comparison of these two groups to a group where both Creole and manipulatives (MCRE) were employed. All the groups were homogeneous and comparable. A questionnaire consisting of 9 items, selected mainly from the literature, was administered to all the groups first as a pre-test and then with minor modifications, while retaining the problem structure, as a post-test. ANOVA was employed at 5% level of significance, to determine differential in performance between groups. Post instruction, gain was observed in performance for all groups. Though CRE (L1 group) performed better than ENG, the difference was not found to be statistically significant. MCRE performed better than CRE with statistically significant difference. A second level analysis of the improved performance by ability grouping (High, Average and Low) was also conducted. When L1 was used, only the low ability students (i.e., in CRE) showed significant improvement over the control group. However, when L1 was used together with manipulatives; significant gain was observed over control group for both average and low abilities, with the latter performing at par with average ability students in ENG and CRE.

**Keywords:**

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## Introduction

From a socio-constructivist viewpoint, language and the learning process of Mathematics content are not dissociable. Much of the learning difficulties in Mathematics can be traced down to language difficulties of learners (Clarkson, 1992). During the last thirty years, the body of research which have looked at the interface between language and mathematics proficiency have significantly increased (Pimm,1991; Durkin and Shire, 1991). The problems associated with language and mathematics varies very much on local contexts and studies in this area have looked at different aspects and have taken different orientations over time. For instance, in the United States and Australia, because of their migration history, the interaction of English Language Learners (ELLs) with mathematics has been of main interest. On the other hand, in England the dissonance due to the overlap of the Mathematics and English registers of native English speakers has been a preoccupation. Several other studies have also looked at mathematics ability of bilinguals and multilinguals (Cummins and Swain, 1986; Clarkson, 1992; Barwell, 2003, Bose and Chaudary, 2010). Works by Ellerton and Clarkson (1996) and Setati (2003) support the view that the use of the natural language benefits learners of Mathematics. It is not clear though whether these benefits will be for all learners or just a category of them. Bernardo & Calleja (2005) found that the use of natural language (here Filipino) is advantageous to Filipino-English bilinguals in problem-solving but such advantage was not observed with older students who develop problem solving schema with time (see Bernardo, 2001; Tan and Lan, 2011).

In many countries much of the difficulties in Mathematics content acquisition is due to the utilization of a language of instruction different from the natural language of the learners (Adetula, 1990; Bernardo, 1999). This is particularly true for countries with a colonial history. In Mauritius, Creole is the natural language for the majority of learners, but English is the language of instruction. Much debate has taken place around the language policy in the Mauritian education system. There are voices for and against the use of natural language as the instructional language. In particular, the divide in beliefs on this issue between practitioners and policy makers is apparent. For example, it is not surprising to come across classes where Creole is the medium of instruction (teacher-led) whereas curriculum materials and assessment instruments (state prepared) are still devised in English. Due to a slim body of research in this area much of the debates around the issue of language policy has lacked scientific grounding and it might sound as if a mere switch to L1 will be a panacea of Mathematics underachievement at school.

It is known that Mathematics involves mastery of procedures and understanding of concepts (Orton, 2004). There is also a growing support for the stance that Mathematics is a language in its own (O'Halloran, 1998) whose rules must be grasped. For these reasons, although we believe that a switch from L2 to L1 can have its benefits; these might be marginal compared to strategies which give insight into mathematical ideas themselves. In a review of 14 studies, Ruzic and O'Connell (2001) found that 'use of manipulatives compared with traditional instruction typically had a positive effect on student achievement.' The results of recent research on the effect of manipulatives on mathematics performance are equivocal. Some studies have indicated that the use of concrete materials with college students can have a positive effect on mathematics achievement (Witzel, Mercer and Miller, 2003; Raphael and Wahlstrom, 1989), whereas others have shown conflicting conclusions (Butler, Miller, Grehan, Babbitt and Pierce, 2003). Middle grade students who are low achievers might have more need for concrete materials and would therefore find a manipulative approach to mathematics more conducive to learning than an abstract, symbolic approach (Shoecraft, 1972). High-achieving students, on the other hand, would likely be less affected by instructional methods (Threadgill-Sowder and Juilfs, 1980).

Research at the secondary level has been more oriented towards learning disabilities students and the use of Concrete-Representational-Abstract approach (Butler et al., 2003). Most of these studies were conducted with small group of students or on a one-to-one basis. Few studies have been conducted on the use of manipulative for solving word problem under normal classroom condition and even fewer studies considered the use of manipulatives for solving word problem with 8$^{th}$ grader of various abilities. This study investigates the use of natural language and manipulatives in solving word problem under classroom condition and involves grade 8 students with low, average and high abilities. The aim of this study is to establish whether:

(i) use of Creole improves achievement in Mathematics
(ii) use of manipulatives together with Creole has a positive effect on achievement
(iii) use of Creole is beneficial for all ability groups of students
(iv) use of manipulatives together with Creole has a positive effect on achievement for all ability groups.

## Literature Review

Language plays an important role in the teaching and learning of mathematics (Ríordáin and Donoghue, 2006). The issue of learning and teaching mathematics in a second language has been studied extensively in other countries, for instance in USA, Canada, South Africa, Australia, New Zealand, Spain and UK. In fact, 'fluency in it [language] provides access to the whole world of mathematics' (Esty, 1992, p. 32). However, there are conflicting views about the learning of mathematics in a second language at all levels of education. Some studies have found positive correlations with learning mathematics in a second language and academic achievement (Barwell, 2003; Williams, 2002), while other studies put forward concerns that such pupils underachieve in mathematics (Barton et al, 2005; Gorgorió and Planas, 2001; Marsh, Hau & Kong, 2000). Latu (2005) gather enough evidence in his study to support the theory that students who use their mother tongue while learning in English perform better than those who don't. Ellerton and Clarkson (1996) discussed how difficult aspects of mathematics vocabulary involve many ways in which the same mathematics operation can be signaled. Multiple meanings of familiar words cause reading problems in mathematics (Dale and Cuevas, 1987; Mousley and Marks, 1991). Fasi (1999) found that words with multiple meanings in mathematical contexts become sources of confusion for Tongan students.

Many students are confronted with a range of linguistic difficulties when learning mathematics. One of these difficulties arises when their first language does not have the vocabulary to express the mathematical ideas that they learn in the classroom. Mathematics vocabulary includes words that are specific to mathematics such as quotient, and coefficient. These words like many others have no translation for them in their first language. In addition to isolated vocabulary items, the mathematics register uses its special vocabulary to create complex strings of words or phrases (Halliday, 1975). Often two or more mathematical concepts combine to form a new concept, making the task more difficult to understand (Mousley & Marks, 1991). Dawe (1983) and Clarkson (1992) found that switching languages was a common practice of bilingual students with whom they worked, particularly when the perceived difficulty of the task increased. Code-switching entails switching by the teachers and/or learners between the language of instruction and the learners' main language (Fasi, 1999; Setati & Adler, 2001). Setati (1998) found approaches to teaching mathematics in which bilingual students were urged to construct their own mathematical understanding, encouraged them and their teachers to use code-switching in a range of different situations. There is a considerable literature on the linguistic features of mathematical discourse in English, however limited research on the difficulties these cause for mathematics learners, particularly at lower secondary level. Abedi (2001) is one of a limited corpus that has focused on elementary mathematics.

There is much research on the use and efficacy of manipulatives for primary school as well as students with disabilities, but not much for secondary school students (Weiss, 2006). This lack of research may be due to the perception that manipulatives are not useful for older students and are more useful with lower ability students (Friedman, 1978). Moyer (2001) observed that middle grade teachers found the use of manipulative in class as 'fun, but not necessary, for teaching and learning mathematics'. Though, curriculum developers strongly urge the use of manipulatives, many studies report a decline in its use from primary school (Hatfield, 1994) into secondary School (Suydam, 1984). Friedman (1978) inferred that manipulatives were useful only at first grade level. However, other studies show that it is more likely that manipulatives would increase in value in later grades as children mature and become mentally able to develop understanding of operations (Susan, 1998)

In a review of the use and effectiveness of manipulatives on student achievement in mathematics, Suydam and Higgins (1977) reported 40 studies: 24 studies showed significant positive effects on student achievement, 12 studies showed no differences and 4 showed significant differences favoring non-manipulatives groups. However the quality of these studies may be problematic as many of them had various methodological flaws making the findings somewhat suspect (Raphael and Wahlstrom, 1989). In a meta-analysis of 60 studies at elementary level, Sowell (1989) found that instruction of a year or longer with concrete models improves performance in the classroom, whilst, short term use of manipulatives made no difference in test scores.

## Methodology

Permission was granted by the Ministry of Education and Human Resources to access the school and collect data for the survey. Subjects were ensured confidentiality of the data gathered. One thousand and thirty seven (1037) grade 8 students, involving 29 classes from 13 schools, participated in a preliminary mathematics test, used for sampling purposes. 24 classes (12 Boys and 12 Girls) involving 918 students were retained for the study (plus one additional class for piloting purposes). Based on the mathematics test, the 918 students were divided into 3 ability group (high, average and low). The preliminary mathematics test was constructed consisting of 22 questions (17 questions from grade 7 syllabus together with 5 simple word problem) printed on 4 pages. The objective of the test was to categorize the student into ability groups. The test was piloted with nine grade 8 students from different schools with different abilities. The test was then finalized and administered. A marking scheme was developed for consistent correction and maximum score for the test was 70 marks. Three equivalent questionnaires were constructed for pretesting and post testing. The items were multistep word problems adapted from past exams papers, research papers and Australian Mathematics Competitors questions. An initial questionnaire of 16 questions was designed and piloted with 90 students (3 groups of 30 students with high, average and low ability). Following the piloting, the questionnaire was amended and 10 items were retained. After further piloting, the pretest/posttest was reviewed and only 9 items were retained with a maximum score of 36 marks. 23 items were divided into two worksheets with 12 and 11 items respectively. The worksheets contained multistep word problems involving the four basic operators ($+, -, \times, \div$). A set of teaching aids was developed by the researcher. The aim of the manipulative was to help students represent the problem so that they can better understand the structure of the problem. Examples of manipulatives used were: paper money, model ladder, coins, shapes made of Bristol paper, small square of Bristol paper with dots for counting purposes, hollow pipes representing objects.

The study was conducted during the first and second term of 2011. During the first term, the preliminary mathematics test was administered. Based on the scores, students were categorized into three ability group as follows: High Achievers (Marks $\geq$ 50); Average Achievers (30 $\leq$ Marks $<$ 50); Low Achievers (Marks $<$ 30). Each ability group was further divided into 4 subgroups and randomly assigned to a control and three different treatments.

Each subgroup consisted of two classes (one boy and one girl). However, only two treatment and the control groups are reported in this paper. They are as follows:

1. Using English (L2) as teaching medium – ENG (Control group)
2. Using Creole (L1) as teaching Medium- CRE
3. Using manipulative as teaching tools and Creole as teaching Medium - MCRE

Subjects from the 12 subgroups (24 intact classes) took a one-hour pretest at the beginning of the second term. The pretest was also used for selection of homogeneous groups, but the subjects were unaware of who forms part of the survey. In this way, performances were comparable for different treatments. The pretest was marked based on a marking scheme devised by the researcher. Each group attended at least two training sessions totaling 160 minutes to work out the worksheets. Most of the sessions were conducted during activity periods which are scheduled twice a week.

- Control group (ENG): Subjects were taught in English in the traditional manner. That is, the researcher worked out a problem as an example and asked subject to solve another problem and finally correcting the problem.
- Treatment 1 (CRE): Subjects were taught using Creole as teaching medium. The researcher proceeded as for the control group but used Creole as teaching medium instead of English, while retaining the technical terms in English.
- Treatment 2 (MCRE): Subjects were shown how to use the manipulatives to solve the problem. Creole was used as the teaching medium. At the end of the lesson, the researcher corrected all the problems on the board. Alternative methods were welcomed.

One-hour posttests were administered one to three days after the training sessions. The marks were then input in statistical software (SPSS) for analysis. ANOVA was used to analyze the data. After eliminating subject who were absent during any one of the sessions (pretest, training or posttest), only 501 students were retained. However, data reported in this study is based only on the control and two different treatments, involving 366 students.

The preliminary mathematics test as a set was found to be very reliable with Cronbach alpha greater than 0.8. Also, the pretest and posttest as a set proved to be reliable with Cronbach alpha 0.651 and 0.669 respectively.

Correction of both preliminary mathematics test and the pretest/posttest were made according to Marking Schemes by an experienced teacher and the researcher respectively. Both have at least eleven years of teaching experience at secondary level and have marked scripts for the National Cambridge

Examination for at least eight years. All training sessions were conducted by the researcher in order to reduce variation due to different teaching styles.

## Results and Discussions

*Scores for Overall Sample*

The posttest results indicate a gain in performance, (Table 1 and Figure 1) for all teaching strategies. In order to investigate any statistically significant difference in performance between the strategies, an Analysis of Variance (ANOVA) was carried out. The Levene test showed that the assumption of homogeneity of variance was violated, $p<0.05$, hence the Welch test was used (Field, 2005). For the whole sample (n=366), no significant difference was observed in pretest performance, $p>0$, however significant difference $W(3,269.494) = 5.003$, $p<0.05$, was noted in posttest performance due to the choice of strategy. Contrast tests, reported in Table 2, sheds more light on the occurrence of such differences. Post-tests analyses reveal no significant difference in performance between ENG and CRE groups. Since the performance of these two groups were indistinguishable in the pre-test as well, the choice of language is not found to impact on achievement levels of students on worded tasks. However, the MCRE group performed significantly better than both the ENG and CRE group. This shows that teaching strategies may influence performance.

**Table 1.** *Mean Scores and Standard Deviations for Pretest and Posttest*

| Teaching strategy | | Pretest | | Posttest | |
|---|---|---|---|---|---|
| | N | Mean | Std D | Mean | Std D |
| Eng | 114 | 15.47 | 7.679 | 23.83 | 8.232 |
| Cre | 119 | 15.56 | 6.489 | 25.33 | 6.994 |
| MCre | 133 | 16.36 | 7.526 | 27.29 | 6.020 |

**Figure 1.** *Pre/Posttest Scores Overall*

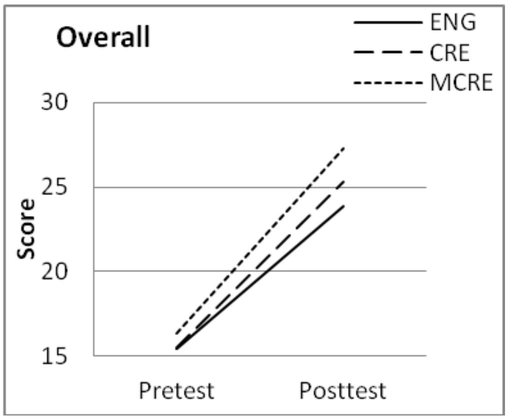


**Table 2.** *Contrast Test Conducted on Post-Test Performance*

| | Posttest | | |
|---|---|---|---|
| | Value of Contrast | t | Sig. (1-t) |
| Eng-Cre | -1.49 | -1.490 | .069 |
| Eng-MCre | -3.45 | -3.708 | .000 |
| Cre-MCre | -1.96 | -2.368 | .019 |

*Scores by Ability Levels*

Independent of the teaching strategies employed, all ability groups improved their performance from pre-test to post-test as shown in Table 3 and Figure 2. The gross mean mark for all ability groups in the pre-test and the post-test are shown in Table 4. The pre-test's order in performance between the ability groups was maintained in the post-test with the high ability group still scoring the highest (mean 32.1) and the low ability group the lowest (mean 21.3). The improvements attained were found to be a function of the ability grouping. The ratio of post-test gross mean mark to pre-test gross mean is computed to show the relative improvement. It is clear that the greatest gain achieved was in the low ability group, with a gain factor of 2.2 compared to 1.40 and 1.6 in the high and average ability groups respectively. A detailed analysis of the contribution of each strategy within each group is next presented.

**Table 3.** *Performance of Students in Pre-Test and Post-Test, by Ability Groups and Teaching Strategy*

| Ability | Teaching Strategy | | Pretest | | Posttest | |
|---|---|---|---|---|---|---|
| | | n | Mean | SD | Mean | SD |
| High | Eng | 36 | 23.47 | 3.443 | 32.08 | 3.901 |
| | Cre | 33 | 21.94 | 4.220 | 31.70 | 3.746 |
| | MCre | 48 | 22.90 | 6.278 | 32.40 | 3.221 |
| Average | Eng | 40 | 14.23 | 5.201 | 22.55 | 5.991 |
| | Cre | 55 | 15.13 | 5.368 | 22.93 | 6.495 |
| | MCre | 42 | 14.81 | 5.316 | 25.12 | 5.129 |
| Low | Eng | 38 | 9.21 | 6.010 | 17.37 | 6.619 |
| | Cre | 31 | 9.55 | 3.510 | 22.81 | 6.306 |
| | MCre | 43 | 10.58 | 4.573 | 23.70 | 5.374 |

**Table 4.** *Relative Improvement from Pre-Test to Post-Test Expressed as the Ratio of Gross Mark in Post-test to Pre-test for the Different Ability Groups*

| Ability group | Gross mean | | Ratio |
|---|---|---|---|
| | Pretest | Post test | Posttest/Pretest |
| High | 22.8 | 32.1 | 1.4 |
| Average | 14.8 | 23.5 | 1.6 |
| Low | 9.83 | 21.3 | 2.2 |

**Figure 2a.** *Pre/Posttest Scores for HA*

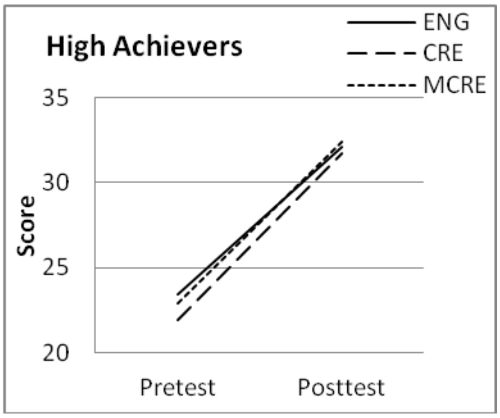



**Figure 2b.** *Pre/Posttest Scores for AA*

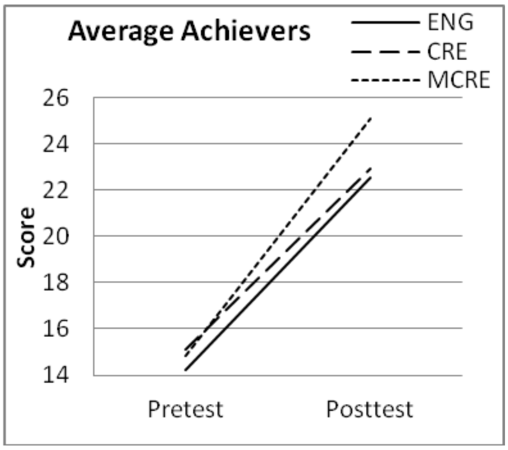
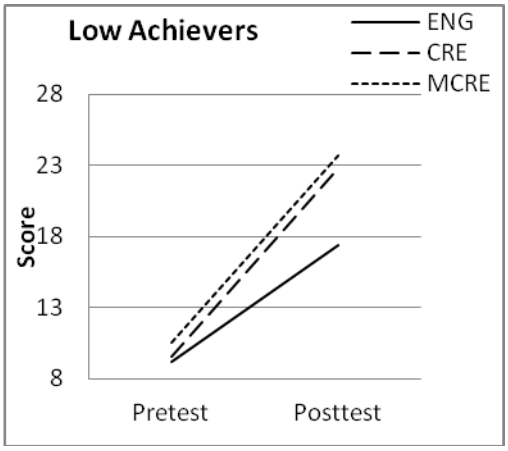



**Figure 2c.** *Pre/Posttest Scores for LA*




Among high achievers the teaching strategies employed produced no statistically significant gain in performance over control group in the post-tests. All three strategies resulted in comparable mean performance (around 32 marks) and standard deviations (3.2 – 3.9 marks). However, it is to be noted that the standard deviations from pre-test to post-test remained comparable for ENG and CRE, but showed a two-fold contraction for MCRE. This indicates that the use of manipulatives in conjunction with Creole narrows the gap in performance among high achievers, leading towards greater homogeneity within the group.

For average achievers, an analysis of variance confirmed comparability in the performance of students in ENG, CRE and MCRE in the pre-test, but statistically significant difference between these groups in post-test. The influence of language on performance is insignificant in this ability band. However, the use of manipulatives impact significantly on achievement among the average achievers. For this ability group, it is observed that MCRE (mean 25.12) group tend to perform significantly better in post-test than CRE (mean 22.55) and ENG (mean 22.93) groups (Table 5).

**Table 5.** *Contrast test for Posttest for Average Achievers*

| | Posttest | | | |
|---|---|---|---|---|
| | Value of Contrast | t | Df | Sig. (1-t) |
| Eng-Cre | -.38 | -.297 | 191 | .767 |
| Eng-MCre | -2.57 | -1.904 | 191 | .029 |
| Cre-MCre | -2.19 | -1.751 | 191 | .041 |

The teaching strategies employed have worked differently for the case of low achievers. The MCRE groups and CRE groups achieved higher mean scores (23.7 and 22.8 respectively) compared to the ENG group (17.4). Contrast tests show that these differences are significant (Table 6). The difference between the mean scores for MCRE and CRE group was not statistically significant. When the achievement of the CRE and the MCRE groups in the low ability band is compared to the corresponding groups (and even ENG) in the average ability groups a leveling of performance in the post-test is observed. Such equilibration in performance is found to be important given the statistically significant difference noted between these groups during pre-test. Statistical test confirmed no significantly difference during post-tests between the average ability and the low ability groups.

**Table 6.** *Contrast Test for Posttest for Low Achievers*

| | Posttest | | | |
|---|---|---|---|---|
| | Value of Contrast | t | df | Sig. (1-t) |
| Eng-Cre | -5.44 | -3.688 | 143 | .000 |
| Eng-MCre | -6.33 | -4.666 | 143 | .000 |
| Cre-MCre | -.89 | -.621 | 143 | .268 |

## Conclusion

The teaching of mathematics is done in many countries in a language other than the natural language. There have been a lot of debates upon the impact of these practices on underachievement in Mathematics and possible yields that a switch to the natural language could generate. This work looks at the question from two different perspectives. We claimed that Mathematics is a subject which has its own language and being proficient in Mathematics is not only a question of comprehension of instruction but also involves a proper grasp of concepts. The quasi-experimental study shows effectively that natural language is a factor which can lead to improvement in mathematics achievement. However, the improvement obtained is not generalized and is a function of student's ability groups. Students who are high or average achievers in Mathematics do not appear to benefit from the use of the natural language as the language of instruction. It is essentially students who are in the low ability bands who benefit the most. In this group, the impact of performance of Creole is substantial and students are found to equilibrate their performance with average achievers. This behavior of natural language utilization on performance on worded task is attributed to the fact that English as a medium of instruction chiefly poses a problem to low ability students in Mauritius. It is therefore highly probable that intervention in Creole curtails this language barrier and produce higher gains in achievement of these students on worded problems. This work has also shown that switching to the natural language is not the only issue to boost Mathematics achievement. For instance the use of manipulatives was found to contribute significantly in rising performance. In particular, for high and average achievers these strategies proved beneficial. For the low achievers the use of manipulatives did not translate into comparatively better performance compared to the use of natural language. The use of manipulatives is important in making sense of the Mathematics and in concept development. We have argued that Mathematics is a language on its own and a conceptual understanding of Mathematics is important. The results confirm this line of thought. We conclude that the use of natural language in Mathematics should not become a generalized policy and its use should be permissible as a support for low ability students in particular. Other strategies which promote conceptual understanding of Mathematics would also bring about positive results.

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