Palmer, W. P., & Treagust, D. F. (1996). Physical and chemical change in textbooks: an initial view. *Research in Science Education, 26*(1), 129-140.

Sanger, M. J., & Greenbowe, T. J. (1997). Common student misconceptions in electrochemistry: galvanic, electronic, and concentration cells. *Journal of Research in Science Teaching, 34*(4), 377-398.

Sanger, M. J., & Greenbowe, T. J. (1999). An analysis of college chemistry textbooks as sources of misconceptions and errors in electrochemistry. *Journal of Chemical Education, 76*(6), 853-860.

Shiland, T. W. (1997). Quantum mechanics and conceptual change in high school chemistry textbooks. *Journal of Research in Science Teaching, 34*(5), 535-545.

Stinner, A. (1992). Science textbooks and science teaching: From logic to evidence. *Science Education, 76*(1), 1-16.

Tan, K. C. D., & Koh, T. S. (1999). Dissolve or react? *Australian Science Teachers' Journal, 45*(3), 36.

Thiele, R. B., Ventille, G. J., & Treagust, D. F. (1995). A comparative analysis of analogies in secondary biology and chemistry textbooks used in Australian schools. *Research in Science Education, 25*(2), 221-230.

Wilkinson, J. (1999). A quantitative analysis of physics textbooks for scientific literacy themes. *Research in Science Education, 29*(3), 385-399.

FACTORS AFFECTING STUDENTS' ABILITIES TO SOLVE OPERATIONAL AND WORD PROBLEMS IN MATHEMATICS

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This study was designed to identify some of the factors that affect students' abilities to solve operational and word problems in mathematics. The factors examined were language skills, field dependence-field independence cognitive style, gender, ethnicity and basic mathematical skills. A sample comprising of 113 (39 boys and 74 girls) Form IV students from seven secondary schools in the State of Penang was selected for this study. Three instruments were used: Test 1 (consists of 10 operational problems), Test 2 (contains three word problems) and the Group Embedded Figures Test (GEFT). The topic tested was "the negative number." The biodata of each student was obtained from the class teacher. The elements included were gender, ethnicity, grade scored in mathematics and the Malay language performance in the PMR examination. The results show that basic mathematical skills, field dependence-field independence cognitive style and language skills of the subjects are significantly related to their abilities in solving operational and word problems. The regression analysis shows that 43% and 24% of the variance of Test 1 scores and Test 2 scores respectively were accounted for by the above first two factors.

INTRODUCTION

Achievement in mathematics has been found to be related to a number of variables. Smith (1971), Aiken (1971), Adetula (1989), Tow and Lim (1994) have recognised that mathematics difficulties may often be attributed to language difficulties. This is because the ability to understand written mathematical vocabulary is an essential and important skill in solving

mathematical word problems or operational problems involving only arithmetic computation. Furthermore, the nature, semantic structure and symbolic representation of mathematical language are always so much different from the language used in other subjects. Therefore, this study aims to investigate whether language skills play a more prominent role in solving word problems than solving operational problems.

Lim and Lourdusamy (1994), Austin (1979) and McKllip (1966) have shown in their studies that prior knowledge is important for mathematical learning. With a sample of 52 second year university education undergraduates majoring in mathematics, Lim and Lourdusamy (1994) found that prior achievement in mathematics is significantly related to mathematics achievement at the university level. Thus, the authors expect that basic mathematical skills might be related to students' abilities in solving word problems or operational problems.

The field dependence-field independence cognitive style which is related to analytical versus global thinking has been found to be related to achievement in school subjects (Lourdusamy, 1994). The field independent students who are analytically oriented in their cognition are reported (Lourdusamy, Zainal, Gajaraj, Choo & Lee, 1989; Threadgill, 1979; Berenson, 1985) to achieve better in mathematics than the field dependent students. In the Malaysian context, ethnicity is found to be related to mathematics achievement (Salim, 1987; Curriculum Development Centre, 1980 and Lim & Lourdusamy, 1994). The first two studies show higher performance in mathematics by Chinese medium primary school pupils while the latter indicates a similar trend for university students. Studies on gender differences in mathematics achievement revealed inconclusive findings. Some studies (Simpson, 1974; Fennema & Sherman, 1977) show that boys tend to achieve better in mathematics than girls. In a Malaysian study, Lim (1992) found that girls scored significantly better than boys in a sample of Form IV students comprising 185 boys and 148 girls.

This study was designed to investigate whether the above-mentioned factors have an influence on students' abilities to solve operational and word problems in mathematics. The factors examined were language skills, the Malay language, as it is the language of instruction in the teaching of mathematics in Malaysian schools, field dependence-field independence

cognitive style, gender, ethnicity and basic mathematical skills which were based on the students' mathematics performance in the lower secondary evaluation examination (PMR).

More specifically, this study attempts to answer the following questions:

1. Does the students' field dependence-field independence cognitive style (GEFT score) relate to their abilities in solving:
   a) operational mathematical problems;
   b) word problems in mathematics?
2. Do the students' basic mathematical skills relate to their abilities in solving:
   a) operational mathematical problems;
   b) word problems in mathematics?
3. Do the Malay language skill of the students relate to their abilities in solving:
   a) operational mathematical problems;
   b) word problems in mathematics?
4. Do gender and ethnicity of the students relate to their abilities in solving:
   a) operational mathematical problems;
   b) word problems in mathematics?
5. What is the differential contribution of the variables (gender, ethnicity, basic mathematical skills, language skill and Group Embedded Figures Test [GEFT] score) to the students' abilities in solving operational problems?
6. What is the differential contribution of the variables (gender, ethnicity, basic mathematical skills, language skill and GEFT score) to the students' abilities in solving word problems?

METHOD

Sample

A sample comprising of 113 (39 boys and 74 girls) Form IV students from seven secondary schools in the State of Penang was selected for this study. The sample consisted of 74 Malay, 25 Chinese and 14 students from other races. All the schools were selected randomly but all the students selected had obtained at least a pass grade in mathematics and the Malay language in the lower secondary evaluation examination (PMR).

Instruments

The present study utilized two written tests, Test 1 and Test 2 as well as the Group Embedded Figure Test (GEFT) designed by Witkin, Oltman, Raskin and Karp (1971). Test 1 consisted of ten operational questions based on the topic "negative numbers." The negative numbers included were in the form of integers, decimals and fractions. These questions were transformed from the word problems in Test 2 so that the operational part of Test 2 and Test 1 was exactly the same. Test 2 comprised of three word problems based on the same topic. Each word problem consisted of three sub-questions involving one or more operations. The GEFT is designed in such a way that the subject is at first shown a simple figure. It is then removed, and the subject is required to locate it in a complex design of which it is a part. Each student is given ten minutes to locate the simple figure specified in 18 different figures. The number of correct figures located is taken as the score of GEFT which indicates the position of the individual in the field independence-field dependence cognitive style continuum. A high score indicates a relatively higher inclination towards analytical thinking or less inclination towards global thinking whilst a low score indicates a relatively higher inclination towards global thinking or less inclination towards analytical thinking.

Procedure

All the three tests (GEFT, Test 1 and Test 2) were given at different times but within a week. The biodata of each student was obtained from the class teachers. The elements included were gender, ethnicity, grades scored in mathematics and the Malay language in the PMR examination. The data

collected was analysed by using the SPSS for Windows Package. Descriptive statistical tests, the t-test, two-way ANOVA and multiple regression were used in the analysis of the data.

RESULTS AND DISCUSSION

Table 1 below shows the correlation between the dependent variables, the students' abilities in solving mathematical operational or word problems and the independent variables, the GEFT score, the Malay language skill, basic mathematical skills, ethnicity and gender.

Table 1
Correlation matrix of GEFT score, Test 1 and Test 2 scores with the independent variables

Variables	**GEFT score**	**Test 1 (operational)**	**Test 2 (word problems)**
GEFT score	1.0000**	0.4926**	0.3463**
Malay language skill	0.2908*	0.3952**	0.3376**
Basic mathematical skills	0.3425**	0.5741**	0.4478**
Ethnicity	0.1814	0.4210**	0.2050
Gender	-0.2340	-0.0927	-0.0430

No. of Cases = 113 *correlation significant at 0.01 level
**correlation significant at 0.001 level

The result suggests that students' field dependence-field independence cognitive style (GEFT score) is positively correlated to their abilities in solving operational mathematical problems and word problems in mathematics. The data also show that students' basic mathematical skills are significantly correlated with their GEFT scores at the 0.001 level of significance and with their language skill at 0.01 level of significance. The findings thus support earlier studies that field dependence-field independence cognitive styles are significantly related to mathematical skills.

As expected, language skills and basic mathematical skills are significantly correlated to the students' abilities to solve operational/word problems in mathematics. However, it is interesting to note that both language skills and basic mathematical skills have a higher correlation with the students' abilities to solve operational mathematics problems than their

abilities to solve mathematical word problems. The authors would have expected that language skills played a more important role in solving word problems than operational problems.

To determine whether there is any difference between the level of performance in Test 1 and Test 2, a pair-wise t-test was used.

Table 2
t-test comparison between Test 1 score and Test 2 score

variable n	**n**	**correlation**	**2-tail sig.**	**Mean**	**SD**	**t**	**p**
Test 1	113	0.465	0.0000	6.9027	2.581	11.25	0.000
Test 2			4.2832	2.153			

Table 2 shows that Test 1 is significantly correlated to Test 2. This is as expected because all the questions of Test 1 are in fact equivalent questions of Test 2 but written in an operational format. The mean score for Test 1 is much higher than the mean score of Test 2. The data suggest that students' abilities in solving operational problems are higher than their abilities in solving word problems. It also implies that Test 2 is more difficult for the students than Test 1.

To further identify the interactions between the different independent variables and the students' abilities in solving operational mathematical problems and word problems in mathematics, an analysis of variance was carried out separately for both Test 1 and Test 2. The results of this analysis are shown in Table 3 and Table 4 below.

Table 3
Means, standard deviations and analysis of variance results using the scores of Test 1 (operational mathematical problems) and Test 2 (mathematical word problems) as dependent variable.

				TEST 1		**TEST 2**	
Variables		Group	n	mean	s.d.	mean	s.d.
Basic	1.	Very Good	15	8.5333	1.3558	5.8667	1.7674
Mathematical	2.	Good	28	7.9286	1.5618	5.0714	2.0893
Skills	3.	Average	69	6.1739	2.8178	3.6087	1.9942
		T-test		**		**	
Language	1.	Very Good	31	8.0000	1.7321	4.9677	1.9233
Skill	2.	Good	35	7.7714	2.0592	4.8571	2.1302
	3.	Average	47	5.5319	2.7964	3.4043	2.0394
		T-test		**		**	
GEFT	1.	High	33	8.4242	1.6589	5.4848	2.1083
	2.	Medium	53	7.0377	2.2357	4.0755	1.6739
	3.	Low	27	4.7778	2.7642	3.2222	2.4073
		T-test		**		**	
Ethnicity	1.	Malay	74	6.0135	2.6249	3.8784	2.0737
	2.	Chinese	25	8.7200	1.2423	5.2800	2.1510
	3.	Others	14	8.3571	1.6458	4.6429	2.0609
		T-test		**		*	
Gender	1.	Male	39	7.2308	2.0833	4.4103	2.4030
	2.	Female	74	6.7297	2.8056	4.2162	2.0223
		T-test		NS		NS	

** p significant at 0.001 level * p significant at 0.01 level NS not significant

Comparing the means of the scores in Test 1 and Test 2 in Table 3 , it is seen that there is a similar trend relating the various independent variables to the students' abilities in solving operational and word problems in mathematics. However, it appears quite consistently; the students' abilities in solving operational problems are much better than their abilities in solving word problems irrespective of their differences in basic mathematical skills, language skills, field-dependence-field independence cognitive style, ethnicity and gender.

Basic Mathematical Skills and Malay Language Skills

The expected trend that students with better basic mathematical skills and language skill will have better abilities in solving operational and word problems in mathematics is borne out in the results of this study. A multiple comparison of means by using Scheffe's test was then carried out. The result shows that the difference is significant between the average group with the very good group as well as between the average group and the good group only. Nevertheless, students with better language skills still do not show a better score in solving word problems than mathematical operational problems. The findings of this study suggest that students' abilities in solving word problems might be influenced by other factors such as students' problem solving skills and the semantic structure of the word problem itself.

Field Dependence-Field Independence Cognitive Style

The results of the study also indicate that the field dependence and field independence cognitive styles of the students are related to their abilities in solving operational and word problems in mathematics. The students with high GEFT scores have done better in both Test 1 and Test 2 than the students with low GEFT scores. The difference in the performance of the group is statistically significant at the 0.001 level. A multiple comparison of means using Scheffe's test was then carried out. The result shows that the difference is significant between high GEFT scorers and medium GEFT scorers as well as high GEFT scorers and low GEFT scorers. This finding is in keeping with the findings of Lourdusamy and colleagues (1989), Threadgill (1979) and Berenson (1985). In all these studies, the field independent (higher GEFT score) students who are analytically oriented in their cognition are reported to have achieved better in mathematics than field dependent students.

Ethnicity

The ethnicity of the sample is found to interact with both the scores of Test 1 and Test 2. The Chinese students show higher abilities in solving operational and word problems in mathematics than the Malays and others. A multiple comparison of means by using Scheffe's test was then carried out. The result shows that the difference is significant between Chinese

and Malay students only. This finding is consistent with the findings of Salim (1987), the Curriculum Development Study (1980) as well as Lim and Lourdusamy (1994). The difference in mathematics achievement among the different ethnic groups seems to have carried through from the primary school level to the university level.

Gender

It is interesting to note that gender has no significant interaction with students' abilities in solving operational and word problems although boys score a little better than girls in both Test 1 and Test 2. The result suggests that there is no significant gender difference in mathematics achievement and it is inconsistent with other Malaysian study (Lim, 1992) and many other studies (Simpson, 1974; Fennema & Sherman, 1977).

Regression analysis

A stepwise regression analysis was then carried out, using the Test 1 score and the Test 2 score (separately) as the criterion variable to look at the differential contributions of the predictors. The results are presented in Table 4 and Table 5 below.

Table 4

Stepwise Regression Analysis using score of Test 1 (operational problems) as criterion variable

Variables	**R^2**	**R^2 adjusted**	**Standard error**	**F Value**	**Significant F**
Basic Mathematical					
Skills	.32596	.32352	2.12259	54.56356	.0000
GEFT	.42880	.41842	1.96809	41.28914	.0000
Ethnicity	.49495	.48104	1.85911	35.60606	.0000

As revealed in Table 4, the variable basic mathematical skills was the best predictor of students' abilities in solving operational problems. It alone contributed about 33% of the total variance of the Test 1 score. When the GEFT score was taken into account, it contributed another 10% of the total variance. The third predictor was ethnicity which contributed another 7% of the total variance. Thus, in total 49% of the variance in the Test 1 score is accounted for by basic mathematical skills, GEFT score, and ethnicity of

the students. Language skills and gender do not seem to contribute much in solving operational problems in mathematics.

Table 5

Stepwise regression analysis using the score of Test 2 (word problems) as the criterion variable

Variables	R^2	R^2 adjusted	Standard error	F Value F	Significant
Basic Mathematical Skills	.20050	.19330	1.93333	27.83675	.0000
GEFT	.24266	.22889	1.89020	17.62268	.0000

A rather similar trend is observed when the students' abilities in solving word problems (Test 2 score) were used as the criterion variable. As presented in Table 5, the component, basic mathematical skills was the best predictor of students' abilities in solving word problems. It alone contributed 20% of the total variance of the Test 2 score. When the GEFT score was taken into account, it contributed another 4% of the total variance. Thus, about 24% of the variance in Test 2 score is accounted for by basic mathematical skills and the GEFT score. The remaining 76% of the total variance of the Test 2 score was unaccounted for. Language skills do not seem to contribute significantly in solving word problems. This is rather a surprising result because one would expect the solving of word problems to be related to reading and comprehension skills. The PMR language paper (Malay language) tests the general language skills of students. Only specific language skills like reading and comprehension may be related to the solving of word problems and not to the general language skills. This may be the reason why the language skills measured here do not seem to contribute to solving word problems.

CONCLUSION

The results of this study indicate that students have better abilities in solving mathematical operational problems than in solving word problems. Factors such as basic mathematical skills, language skills, field dependence-field independence cognitive style and ethnicity have significant correlations with the students' abilities in solving operational and word problems. However, basic mathematical skills seems to be the best predictor of the

students' abilities, followed by the field dependence-field independence cognitive style. Hence, measures should be taken to upgrade students' basic mathematical skills as mathematics is a hierarchical subject. Higher order concepts are dependent on lower order concepts while the acquisition of basic mathematical skills is always a pre-requisite of problem solving skills.

With regard to the different cognitive styles of students, teaching strategies and approaches might need to be varied in classroom teaching so that students with field dependent cognitive style would not be disadvantaged and appear to left behind.

REFERENCES

Adetula, L. O. (1989). Solutions of simple word problems by Nigerian children: Language and schooling factors. *Journal for Research in Mathematics Education, 20*(5), 489-497.

Aiken, L. R. (1971). Language factors in learning mathematics. *Review of Educational Research, 42*(3), 359-385.

Austin, J. D. (1979). High school calculus and first quarter college calculus grade. *Journal for Research in Mathematics Education, 10*(1), 69-72.

Berenson, S. B. (1985). Using the computer to relate cognitive factors to mathematics achievement. The Florida State University. *DAI, 46A*: 2605; March 1986.

Curriculum Development Centre (1980). *Taraf pencapaian murid-murid sekolah rendah di Malaysia* (The standard achievement of primary school children in Malaysia). Kuala Lumpur: Kementerian Pendidikan Malaysia.

Fennema, E., & Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization and affective factors. *American Educational Research Journal, 14*, 51-71.

Lim C. S., & Lourdusamy, A. (1994). Interaction of prior knowledge, race and cognitive style with mathematics achievement at the first year university level. *Journal of Science and Mathematics Education in South East Asia*, Vol. XVII, No. 2.

Lim C. S. (1992). *Relationship between computer literacy and mathematics attitude*. Unpublished M.Ed dissertation. University of Malaya.

Lourdusamy, A. (1994). *Perbezaan gaya kognitif individu dan implikasinya terhadap pendidikan*. Syarahan Perlantikan Profesor Baru. University of Science Malaysia.