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Assessing the Response of Bilingual Arab Students to Precalculus Word Problems in English Language

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Abstract

This paper presents a qualitative and quantitative study on the response to word problems of bilingual Arab students in a preparatory year math program, in an English medium university. Dichotomous and polychotomous grading schemes were used in order to investigate the students' responses to word problems. Among the results, it was found that the more linguistically loaded a word problem is the more likely students may try to avoid them. The students didn't seem to follow any known strategy for solving word problems. Moreover, guessing levels seemed to be higher in word problems. Some educational implication of this study and recommendations are enumerated.

Background of the study

Students newly admitted at King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia come from Arabic medium schools, whereas, the language of instruction at KFUPM is officially English. Therefore, students are required to undergo an intensive one year English language program to get them acquainted with the new language of instruction. This intensive year program is called the preparatory year (or orientation program). In addition to developing the proficiency level of the students in the English language, the students also take two pre-calculus algebra courses. These courses serve two purposes: (1) they help the students to review some high school algebra that are needed in calculus, and (2) they introduce students to learning mathematics through the English medium.

During the preparatory year, a good number of students face problems in mathematics despite the fact that the material was fully covered in high school, and the students are largely considered above average among the high school graduates in the Kingdom. This problem is more compounded if the students are confronted with word problems. The difficulty is usually attributed to the students' lack of mastery of the English language, though the problems in some cases are mathematical in nature.

In word problems, we observed that students can miss the whole question by merely not understanding the meaning of a key word in a question. For instance, a student might miss the meaning of a word like *reciprocal*, *product*, *even*, *sum…* etc. in a question and that may destabilize his understanding completely. As a result, the student cannot develop a mathematical model equation from a given word problem. This type of difficulty may lead to the failure to determine what one is looking for mathematically, and sometimes making sense of the physical meaning of the problem. Moreover, one is sometimes surprised that this class of students do not understand (or find it difficult to solve) an easy but unfamiliarly worded problem even if the mathematical model is given. This is true even when what is required is just a substitution and some algebraic manipulations, which highlight the mathematical aspect of the problem

Based on the above qualitative observations of our students' responses to word problems, we looked into the literature to see if we can get some insights on how to address this problem. This has revealed to us that intensive studies have been done on word problems – its complexity, classifications, etc. However, it can easily be observed that the bulk of these studies were carried out at the primary and secondary school level (K to 12). Few studies were done on how university students respond to word problems, and how is that different from other school levels. What is more scarce in the literature, is how predominantly Arab bilingual university students, who are acquiring English as a language of instruction at the same time learning mathematics, respond to word problems. This study is an attempt to shed some light in this direction. In particular, the study investigates among other questions, the problem solving strategies of bilingual Arab students in solving word problems, language related problems they face in their attempt to solve word problems, and how these problems are hindering them from understanding mathematics. Furthermore, how do these problems affect students' achievement on assessments in mathematics, and how are the students' performances on word problems compared to other symbolic problems?

Literature Review

Student response to word problem is one of the most problematic issues in mathematics teaching and learning. Students, regardless of their background and educational level, find mathematical word problems difficult compared to other algebraic problems that usually require routine procedural approach in solving them. This is to the extent that some students get scared by the mere mention of word problem and try to skip it wherever possible. On the other hand, many teachers acknowledge the fact that word problems are difficult to explain to the students, and consume a lot of teaching time. As a result, some teachers try to avoid word problems in their teaching in order to minimize students' mathematical anxiety on one hand, and to be able to cover the syllabus on the other.

The difficulty of word problem is not unconnected with the complexity involved in the statement of the problem. It is usually a problem that is stated in common language, however, with mathematics fully embedded in it. Furthermore, the process of solving a word problem is a multi-step process, in that, students are required to understand the relevant mathematical concept therein, "mathematize" it into a suitable symbolic representation, then manipulate the symbols, and come out with a meaningful interpretation of the solution to the problem (Brodie, 1989). This synthesis and evaluation process is not that easy for students due to high linguistic and cognitive demands involved in the process. It has been noted that word problems are perhaps the only mathematics problems that require linguistic, cognitive and perceptual skills all in one (Sharma, 1981).

Many reasons have been hypothesized as the possible sources of difficulties in word problems. However, one reason that appears to be obvious and straightforward is students' language difficulties (Murray, 2001). The literature is replete with findings that are pointing to the fact that even students who are learning mathematics in their first language do find difficulties in understanding word problems. The reason is usually connected with language issues. The review done by Ellerton & Clarkson (1996) shows that semantic structure was the main factor contributing to the difficulty of word problems. And that semantics structure has a much more important influence on learning and quality of participation in classroom discourse than other more obvious language variables like vocabulary. For instance, while it appears not much of a problem for most students to manipulate equations like "$I = prt$", putting it as "interest is principal times interest-rate times time" might pose a challenge to student whose algebraic language is divorced from the natural language (Burton 1988). In a study conducted by Abrahams (2001), it was found that students "significantly under-performed on the same content by an average of 18% to 22.8% when tested with the sentence format by comparison with the traditional signs and symbol format".

In his recent paper, Easdown (2006) noted that the reason why mathematics is difficult to communicate is simply due to the wide gap between what he called the gulf between syntax and semantics. While instructors incorrectly assume students understanding the meaning of a group of syntax, students who are mostly reticent about their own misunderstanding are struggling to get behind the meaning (or semantics) to successfully activate their mathematical knowledge and solve these word problems. This language situation is obviously more problematic for bilingual students, whereby word problems are expressed in their second language. In his investigation of the effect of language and modeling word problem solving strategies among bilinguals, Bernardo (2005) highlighted the possibility of linguistic factor affecting the reading comprehension and understanding of the bilingual students. This corroborates earlier findings by Barton & Barton (2003) which showed that bilingual students have 10% disadvantage to first language students in textual comprehension. They have gone further to argue that the difficulties in word problems are much more than the lack of understanding of some key words, but rather the possibility of misinterpreting the words outside the terrain of mathematics.

Another common problem that is adding to the difficulty of word problems has been attributed to both teachers' and students' perceptions and beliefs of what mathematics is all about (Murray, 2001). As the saying goes: "What we think it is determines how we teach it" (Watson, 1976). Traditionally, the approach used in teaching mathematics is symbolic in nature and the emphasis is on the procedure to solve a given problem. A word problem is given as an application of some concept or theorem, usually at the end of the topic with a view of using this as an example of real – world application of mathematics (Verschaffel & De Corte, 1997). This procedural approach of teaching mathematics, which dominates many mathematics classrooms, has not given enough practice and training to the students to be able to tackle the complexity of word problems (Cheri, Czarnocha, & Prabhu, 2006). Although this has long been realized and some mathematics educator have already started to reconsider word problem as a vehicle of developing students' problem solving capacity and making lessons more pleasant and enjoyable (Verschaffel & De Corte, 1997), not much progress has been achieved in making word problems student-friendly (Kwari & Weseels, 2003). In their review of the literature, Valentine & Sam (2004) have shown that several studies have pointed to the fact that ineffective instruction has been among the reasons that are making word problems difficult. Other factors that contribute to the difficulty of word problems, as noted in Valentine & Sam (2004), include the processing skills of pre-requisite knowledge necessary, cognitive ability required the semantic structure of the word problems, and some less influential factors like: context, binary steps and superfluous information in the problems.

Theoretical Framework

Word problems have received a lot of attention from researchers and mathematics educators, perhaps because it has been perceived as a vehicle of bridging the huge gap between school mathematics and daily-life applications. But they have been viewed differently by researchers. Craig (2002) identified three different ways researchers view word problems. First: "by their structure, appearance and the inbuilt assumptions", second, "by their use as a tool, rather than by their characteristics", and third, "by creating a framework in which multiple types of mathematical problem can be placed, of which word problems are only one".

In this study, we operationalize the definition of word problem by contrasting it to symbolic algebra problems. That is: a word problem is defined as an algebra problem presented fully or partially in the English language, where some command of English language and knowledge of some English vocabularies are required to understand it.

Methodology

Participant

The participants of this study are male students with an average age of 18 years, mostly fresh from high school. Almost all of these students have Arabic as their first language as well as the language of instruction during their high schooling. Most of them have very little English background at the time of admission. On their arrival at the university the language of instruction is changed to English, and the rigor of the program is far higher than what the students were used to in high schools.

Two classes of students from the Spring of the 2005 -2006 academic session participated in this study. That is Math 001 (First Preparatory Year Math), consisting of 231 students. And Math 002 (Second Preparatory Year Math), consisting of 827 students.

The Instrument

Two sets of Exams were used to collect data for this study: the Midterm Exam for Math 001 and that of Math 002. The exams are all in the multiple-choice format, in which students are required to solve the question in the exam booklet and bubble the correct answer in the OMR (Optical Mark Recognition) sheet, which is a form used for scanning and machine scoring. Out of the 25 questions in each of the two exams, only four questions were selected in each exam. And the selection was based on our framework of what word problem is, as discussed earlier. The coefficient alpha reliability index for these exams, as shown in Table 1 below, ranges from 0.728 to 0.802 for Math 001 and from 0.647 to 0.744 for Math 002. The overall reliability for Math 001 is 0.765 while for Math 002 is 0.703 which are reasonable for short length tests of 25 items. In addition to these, Table 1 also shows the number of students tested, their mean and standard deviation under each form of the test.

Table 1. Alpha reliability indices for the MidTerm exam forms of Math 001 and Math 002

Subject	**Form**	**N**	Mean	SD	reliability
Math 001	**001**	65	14.354	4.776	0.802
	002	51	14.020	4.751	0.789
	003	65	15.785	4.160	0.739
	004	50	14.420	4.181	0.728
	Overall	231	14.645	4.467	0.765
Math 002	**001**	206	13.447	3.759	0.647
	002	208	14.120	4.329	0.738
	003	207	13.449	3.989	0.684
	004	206	13.534	4.382	0.744
	Overall	827	13.638	4.115	0.703

Multiple versions of the same test were used to discourage dishonest students from easily peeking at their neighbors to find out answers to questions they don't know. These versions contain the exact same questions that were ordered slightly differently between forms to achieve test security. As indicated by Table 1, there was largely not much difference in student performance between versions of the test.

Aims of the study

The aim of this study is to investigate how bilingual Arab students respond to word problems in their examination. In particular, we want to know how many students attempted the questions, and how many did not. How many students among those who have attempted the question got them right and how many did not. What are the strategies used by the students who got the answer right and what are the mistakes of students who got it wrong? In comparison, how is the students' performance on word problems compare with that of purely symbolic algebraic questions?

Procedure

Two methods of grading were used to answer the research questions: 1) dichotomous and 2) polychotomous. The dichotomous (right vs wrong) grading were done by computer, while a hand grading was done to the sample polychotomously (wrong, partially correct to fully correct). The grading was done carefully with the aim of answering the research question stated earlier.

Result and Discussion

All items in these exams were dichotomously scored. That is, the scoring is done as correct versus incorrect. Table 2 reports the means (M) and standard deviations (SD) of three groups of item: 1) entire items in the exams, 2) word problem items and 3) symbolic items (non word problems) items. In particular, reported in the table are the average and standard deviations of item difficulties and item discriminations as given by both Discrimination Index and the biserial correlation for all the three item groups.

Table 2. Descriptive Statistics of Dichotomously-scored Algebra Problems

Subject		N	Prop. Correct M	Prop. Correct SD	Disc. Index M	Disc. Index SD	Biser. Corr. M	Biser. Corr. SD
MATH 001	**All Items**	25	0.5861	0.1815	0.4209	0.1808	0.3994	0.1808
	Word Problem	4	0.5094	0.2622	0.3063	0.1914	0.3175	0.2482
	Non-word	21	0.6007	0.1597	0.4427	0.1714	0.4150	0.1623
MATH 002	**All Items**	25	0.5451	0.1751	0.3725	0.1184	0.3253	0.1021
	Word Problem	4	0.5706	0.2042	0.3194	0.1376	0.2963	0.1331
	Non-word	21	0.5402	0.1700	0.3826	0.1124	0.3308	0.0951

The table generally shows that the word problems are less discriminating and more variable in discriminating than the symbolic algebra non-word problems which is true for both Math 001 and Math 002. In addition, the word problems are generally more variable in difficulty than the symbolic algebra non-word problems. For MATH 001, word problems appear more difficult for this class of beginning bilingual students. This finding is not surprising as they are in their first semester of learning mathematics in the English medium. However, for MATH 002, word problems appeared to be slightly easier, perhaps because the students are in their second semester and have successfully completed a rigorous English program in their first semester.

For the fact that word problems are generally multi-step and require extra command of the English language than do symbolic algebra problems, dichotomous scoring may not adequately reveal the extent of students' comprehension (or ill-comprehension) of the algebra word problem in real world settings. Thus, we also took extra steps to subject these word problems to an alternative grading that would possibly reveal the language issues surrounding the problems. In the polychotomous grading, our areas of concentration included: Students attemptedness of the question, developing of the appropriate supporting graph, labeling of the relevant quantities or equation needed for the problem, adoption of the correct algebraic procedures, and finally interpretation of the obtained results. Lack of attempts is considered here as lack of understanding of the question. The disadvantage of the polychotomous grading is that it is much more time consuming to accomplish compared to dichotomous grading (which typically are done effortlessly by a scoring machine or a computer program). As such, for the polychotomous grading, not all students' exam papers were graded. For MATH 001, only 48/231 (21%) exams were sampled for grading, and 251/827 (30%) for MATH 002.

Table 3 shows the question stem and distractors, the proportion of those who correctly respond and point biserial of the dichotomous grading of all the word problems.

Table 3. Cognitive Complexity of Mathematics Questions and Statistics when Items were Dichotomously Scored

	Question			Cognitive	Prop	
Subject	**#**	**Stem**	**Distractor**	**Demand**	**Corr**	**Biser**
MATH 001	1	The **coefficient** of x^2y in the **product** $(4x-5y)(2x-y)(3x-4y)$ is equal to	a) -74, b) -10, c) -43, d) 10,e) -33	Low	0.76	0.28
	2	The **sum** of all solutions of the equation $3\|2x+1\|+4=28$ is equal to	a) -1, b) 1, c) 0, d) -3, e) 3	Low	0.69	0.50
	3	If the expression $3x^2+5x+2$ is written in the form $3(x+a)^2+b$, then *ab* is equal to	a) -5/72, b) 49/12 c) -25/36, d) 5/12, e) -5/36	Medium	0.14	0.37
	4	Three students decided to share the cost of a car. By bringing in an addional student, they can reduce the cost of each students by 400 Saudi Riyals. The total cost of the car is	a) 48000 SR, b) 64000 SR, c) 72000 SR d) 44000 SR, e) 52000 SR	High	0.45	0.21
MATH 002	1	The length of an arc that subtends a central angle of 135^0 in a circle of radius 40 ft is	a) 30π feet, b) 20π feet, c) 25π feet, d) 15π feet, e) 35π feet	Low	0.82	0.37
	2	If the **hypotenuse** of a 30^0, 60^0, and 90^0 **triangle** is 10cm, then the **perimeter** of the the triangle is equal to	a) (15+5$\sqrt{3}$) cm, b) (15+5$\sqrt{2}$) cm c) (2+2$\sqrt{10}$) cm, d) (10+10$\sqrt{2}$) cm, e) (10+5$\sqrt{2}$ +5$\sqrt{3}$) cm	Medium	0.63	0.32
	3	If a car with a wheel of radius 40cm is moving with a speed of 120 kilometers per hour, then the **angular speed** of the wheel of the car in **radian per minutes** is	a) 5000, b) 4000, c) 500, d) 3000, e) 50000	High	0.29	0.12
	4	Two buildings are 240 meters apart. The angle of elevation from the top of the shorter building to the top of the taller building is 30^0. If the shorter building is 8 meters high, then the taller building is	a) (8+80$\sqrt{3}$) m high, b) (8+8$\sqrt{3}$) m high c) (8+80$\sqrt{2}$) m high, d) 88 m high, e) (8+8$\sqrt{2}$) m high	High	0.54	0.37

The table also shows our perceptions on how much thinking the solution of a word problem requires. We call this cognitive demand and is divided into three levels: High, Medium and Low. It can also be seen from the table that some questions, like the fourth word problem of MATH 001 and of MATH 002, are linguistically denser than others.

Table 4 shows the result of the polychotomous grading indicating the number and percentage of students who attempted the question by writing something (not necessarily mathematically correct), and those who did not write anything. It is hypothesized that word problems would be difficult to solve completely without writing down the necessary steps. So, the larger percentage of students showing work indicates that students have some level of understanding of these word problems. As such, we see that the fourth word problem in Math 001 appears to be the most challenging for this class of students. In addition, when we compare the percentage of students attempting the questions against the percentage who got it correct (when dichotomously scored), we see that, unlike the rest in Table 4, the fourth word problem in MATH 001 showed more students getting the question correct than the percentage who attempted to solve the problem by showing their work. Since the item was given in a multiple-choice item format, we can attribute this difference in percentage of students attempting and percentage who selected the correct distractor partly to guessing.

Table 4. Number of Students who attempted the question by showing some work

Subject	No.	N	Sample n	Showed work in booklet	No. work shown	Dichotomous Proportion Correct
MATH 001	1	231	48	98%	2%	76%
	2	231	48	96%	4%	69%
	3	231	48	73%	27%	14%
	4	231	48	33%	67%	45%
MATH 002	1	827	251	83%	17%	82%
	2	827	251	80%	20%	63%
	3	827	251	79%	13%	29%
	4	827	251	72%	28%	54%

Table 5 shows the questions and the process required to solve the question. Some questions require only two stages, while others require more, as indicated in the table. The percentage of those who followed the process are also indicated in the table. Furthermore, the table indicates the percentage of students who got the answer correctly with polychotomous grading in comparison with the dichotomous grading. The last column gives the differences between the two grading systems in proportion of students who got the item fully correct.

Table 5. Percent of Students With Correct Solution To Problem

			% of Students with correct attempt						
Subject	**#**	**Correct solution involves**	**& complete drawing**	**Model/ Equation**	**Process**	**Interpretation**	**Corr Written work**	**Prop Corr (dichotomous)**	**Diff in Prop Corr**
MATH 001	1	Algebraic Process & Interpretation			90%	69%	69%	76%	7%
	2	Algebraic Process & Interpretation			73%	63%	63%	69%	6%
	3	Algebraic Process & Interpretation			19%	10%	10%	14%	4%
	4	Model, algebraic process & Interpretation		6%	2%	2%	2%	45%	43%
MATH 002	1	Formula, Algebraic process & Interpretation		47%	49%	54%	54%	82%	28%
	2	drawing, equation, algebraic solution,& Interpretation	38%	27%	27%	33%	33%	63%	30%
	3	equation, algebraic process & Interpretation		27%	21%	6%	6%	29%	23%
	4	drawing, equation, algebraic solution,& Interpretation	29%	32%	32%	27%	27%	54%	27%

What is interesting to note from Table 5 is that the largest difference in student performance under the two grading schemes occurred in the fourth word problem for MATH 001 where the cognitive demand is higher and modeling of real-world problem is required. The large difference in performance between grading schemes is also seen for all the word problems in MATH 002 where the cognitive demand ranged from low to high and modeling of real-world problem with some formula or equation is required.

Concluding Remark

From the result in the tables above, we can make the following conclusions:

1. From the data, we are unable to discern any pattern in problem solving strategies of a majority of the students. What is clear is that many students find it difficult to even attempt the question and most of those who attempted do that incoherently or with no proper mathematical formulation.

2. We also observed that the more linguistically loaded a question is, the more students find it difficult to solve. However, for lightly worded questions with some technical mathematics words (ME) such as *coefficient* and *sum,* the students do not seem to have much difficulty with them.

3. Contrary to what is reported in the literature that students confuse the OE (ordinary English) and ME (mathematics English) in words (such as "product", "expression" etc.) that have conflicting meaning in the two settings, the bilingual students in this study did not seem to face the same problem. A possible interpretation of this is that unlike monolingual students, this class of students might not be aware of the OE meaning of the word. Therefore, the mastery is on the ME, hence they could not have confused it with OE.

4. From Table 2, the performance of the students in word problems is not too far from the overall average, this is contrary to our assumption In fact, in Math 002, the students seem to be doing better in word problems (M=57%) compared to other symbolic algebraic problems (M=54%). However, it should be noted that this is in the dichotomous grading where no showing of work is required. Therefore, the possibility of guessing is extremely high if one compares with the student results in the polychotomous grading in table 5. As clearly indicated in the table, large merging difference existed between the two grading scheme in most of the questions that require modeling of real-world problems with some algebraic equations. These type of word problems posed the most difficulties for students.

5. The variation between the dichotomous and the polychotomous grading is larger in pure word problems compared to the purely algebraic symbolic word problems. In fact, the number of students who did not attempt a question are more in linguistically

denser word problems compared to pure algebraic word problems especially for MATH 001.

6. As clearly indicated in table 2, the more densely worded a question is the more difficult students find in attempting the question. This has resulted in encouraging students to guess, which may actually complicates assessment of students true performance.
7. The implication of (6) is that students may try to skip topics that tend to be difficult to understand due to language difficulties. Not only that, this is also telling us why the students find it difficult to read from the recommended textbook, and the ramification of that to students understanding of mathematics.
8. In general, not all what we defined to be word problem turned out to be difficult for the students. The word problems that students have difficulties with are indeed difficult either due to high linguistic load or cognitive demands or both in the question.
9. Although students have problems with word problems, their algebraic skills also need to be sharpened.
10. Some of the difficulties that students face can be partially alleviated by allocating more class time to teach strategies to these problems and by concentrating to clarify some possible points of students' confusion. Nevertheless, word problems remain more challenging than the purely procedural or symbolic type mathematics questions.

Limitations of the Study

We would like to mention some limitations of this study. These are as follows:

1. The current study is one of the first studies of its kind on bilingual Arab students. As such, only certain aspects of word problem could be investigated in the project setting. Deeper studies are required to investigate the language issues among bilingual Arab university students.
2. Further classification of word problems is needed in future research to identify which class or classes of problems are naturally more difficult for the students to grasp than others, and why.

3. A posthoc, rather than exploratory investigation should be carried out with well prepared questions that will target specific research questions with the aim of teasing out the main issues.

4. The exams in this study were meant to be multiple choices rather than written, whereby students may not necessarily show all their work. So, many final calculations might have been done in the student's minds.

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