The effects of language simplification and pictures on the ability of Emirati university students to comprehend and solve mathematics word problems

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Abstract

This paper presents a study of Emirati university students learning mathematics in a second language (English). The study focused on students' responses to mathematical word problems in different versions: simpler/more complex versions of the problem in English; an Arabic translation of the problem; and the addition of a picture to support the text of the problem. Our findings suggest that neither language simplification nor pictures significantly affect students' comprehension and performance on word problem assessments; the lexical and syntactic features of the word problems have little effect on their understanding and ability to answer the questions presented to them. In addition, evidence suggests that there is no first-language (Arabic) advantage when answering these assessments. These findings are in line with previous studies that found no evidence that simplifying the language of mathematics tests had a significant positive effect on student performance. Implications on the appropriate theoretical perspectives to use when studying the relationship of language and mathematics learning are discussed. In addition, practical recommendations are presented for instructors and professors in 'globalist' multilingual classrooms (Barwell, 2003).

Introduction

Since the founding of the United Arab Emirates (UAE) in 1971, American and British models of tertiary education, with English as the primary language of instruction, have been adopted in various universities. This language policy makes a reasonable degree of competency in English a crucial component of mathematics education among Emirati university students. To staff new tertiary institutions, the country relies mainly on foreign instructors and professors, many of whom are non-Arabic speakers who rarely acquire fluency in Arabic.

It is important to investigate the use of English to teach mathematics in the UAE university context because little research has been conducted for college-level students, particularly among those in the UAE and in neighboring countries that have similar experiences in terms of language policies. One of the few is Yushau (2009) who investigated the effects of English proficiency on the mathematics performance of university students in Saudi Arabia. His research discussed the language-related difficulties these students faced in learning mathematics and the programs the university has adopted to mitigate these difficulties. He concluded by recommending that this issue be further investigated.

Another reason why this study is important is because research on mathematics in 'globalist' classrooms (Barwell, 2003) is scarce. Within his taxonomy of multilingual classrooms, Barwell describes globalist

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instructional settings as those where teaching and learning are conducted in an internationally used language such as English, which is *not widely used in the community where the classroom is located*; such is the case in the UAE (Badri & Khaili, 2014). In contrast, most studies have been conducted in what Barwell (2003) terms 'monopolist' mathematics classrooms, where learning and teaching is done in the majority language of the society (such as in the United States and the United Kingdom) or sometimes in 'pluralist' classrooms, where several of the languages in the wider society are used for teaching (such as in South Africa). Developing an understanding of what works and what does not in the UAE will point towards strategies that could positively impact teaching practices in the Middle East and other globalist contexts.

Literature review

Language

Solano-Flores (2010) suggests a conceptual framework for examining research on language and mathematics education. In this framework, he lists four ways to conceptualize language, which influence how researchers conduct their studies and interpret their findings. According to him, language can be seen as a process or a means of understanding; as a system or a resource for knowledge construction; as a structure or an agent of problem complexity; and as a factor or an extraneous variable in learning. According to Solano-Flores (2010), views of language as a process and as a system are called functional because they emphasize the influence of language on mathematical communication and the development of mathematical knowledge. On the other hand, views of language as a structure and as a factor are called formal because the emphasis is on linguistic groups and the linguistic features of mathematical problems. The researchers in this study have adopted the formal conception of language in mathematics education. In this paper, language, specifically that in written questions, is seen as a medium that can be simplified in order to make mathematical ideas and assessments more accessible for students learning in a second language. As such, the literature reviewed for this study included studies that took this perspective. Furthermore, because research on language and mathematics education at the tertiary level is scarce, literature involving other grade levels is also reported.

The starting point for this investigation was a study describing the language difficulties related to English words that Emirati university students faced in mathematics tests in English (Causapin & Groombridge, 2014). These difficulties have also been reflected in studies involving the performance of English language learners (ELL's) in other countries. For example, Abella, Urrutia and Shneyderman (2005) showed that more items were answered correctly on a first-language mathematics test than on an equivalent English-language mathematics test. Their study included 1,700 4th and 10th grade native Spanish-speaking students in the USA. The limitation of this study is that the equivalent Spanish test was administered 4 to 6 weeks after the English test, making it difficult to discount the possibility that the first-language advantage was because of familiarity with the content and questions previously seen by students on the first test. In addition, important variables such as socioeconomic status and previous schooling in the country of birth were not controlled.

Nevertheless, Abella et al.'s study is in line with others such as that of Bernardo (1999), which found a first-language advantage even though students were taught in English in the classroom. The participants in his study were 2nd to 4th grade students from the Philippines. This study was small in terms of sample size but the results were replicated with another group of 2nd grade students, who he found were more likely to have a correct understanding of mathematics word problems in Filipino and who were more likely to misunderstand the problems when written in English (Bernardo, 2002). Verzosa and Mulligan

(2013) were able to document similar experiences when they studied a small group of 2nd grade "urban poor" 2nd grade students, also in the Philippines. They found that underdeveloped word problem decoding skills, lack of English language knowledge, or limited reading comprehension strategies were more pronounced in this group of students than those commonly reported in the literature.

Researchers have also attempted to identify the language characteristics of mathematics test items that seem problematic for students learning in a second language because there is evidence that linguistic complexity increases the performance gap between them and first-language students (Abedi, 2002; Abedi, Hofstetter & Lord, 2004). For example, Austin and Howson (1979) hypothesized that complicated sentence constructions, long sentences, infrequently used words and phrases, the passive voice, and conditional clauses (if-then statements) result in reading difficulties. Abedi and Lord (2001) outlined similar linguistic features which they used to simplify mathematics questions from the National Assessment of Education Progress (NAEP) mathematics test. In interviews, not only did they find that all groups of students preferred the simplified questions to the original ones, they also discovered that language modification improved the performance of low-level students (especially ELL's and students of low socioeconomic status). Martiniello (2008) produced a list of features that overlapped with those mentioned above, including word length; number of prepositional phrases and participial modifiers; polysemous words; words and expressions that signify particular referents of mainstream American culture; and the presence of relative, subordinate, complement, and adverbial clauses. Her data were gathered from think-aloud interviews with twenty-four 4th grade students, including both ELL's and native English speakers.

A study conducted by Shaftel, Belton-Kocher, Glasnapp, and Poggio (2006), which involved 8,000 randomly selected students, found evidence for significant effects of certain language elements for three different grade levels. For 4th grade ELL's, ambiguous or polysemous words, mathematics vocabulary, pronouns, prepositions, and complex verbs (verbs with 3 or more words such as "had been going" and "would have eaten") had statistically significant negative impacts on performance. For 7th graders, comparative terms (greater than, less than) and mathematics vocabulary had a negative effect. Finally, for 10th graders, problems arose due to mathematics vocabulary and comparative phrases. The researchers hypothesized that 4th graders were more influenced by language because of their less sophisticated verbal skills than 10th graders. For the linguistically more advanced 10th graders, only difficult mathematics vocabulary influenced their performance. Similarly, a more recent study by Ní Ríordáin and O'Donoghue (2011) showed that syntax, semantics, and mathematics vocabulary were sources of difficulty for Irish secondary students who had been previously instructed in Gaeilge and were transitioning into their tertiary level.

Although it seems intuitive and it appears that there is sufficient evidence to support the hypothesis that certain linguistic features make word problems more difficult for students learning mathematics in a second language, this is not the case. Although Abedi, Lord, Hofstetter and Baker (2000) found that linguistic simplifications on an assessment narrowed the gap between ELL's and non-ELL's, they noted the caveat that it did so because it lowered the achievement score mean of non-ELL's. In addition, they found that linguistic modification did not make any notable difference in student performance for the total student sample. A meta-analysis conducted by Kieffer, Lesaux, Rivera, and Francis (2009), which included the often-cited studies of Abedi and his colleagues, did not find evidence that simplifying language had a significant positive effect on performance. In addition, their findings suggested that ELL's performed better if the language of instruction matched the language of the test, refuting other studies that suggested that the first-language is always better. These studies add uncertainty to what is known about the effects of linguistic modifications, how it could be advantageous, and when and in what

situations it could be beneficial for students. As such, it is important to conduct more research in this area, particularly for groups who are not typically represented in the literature.

Pictures

Aside from language simplification, the researchers in this study also hypothesized that pictures make written mathematical questions more comprehensible for students learning in a second language, which should lead to better performance. This assumption is supported by a meta-analysis by Carney and Levin (2002), which confirms that carefully constructed text illustrations generally enhance the performance of learners on a variety of text-dependent cognitive outcomes. The authors structured their work in terms of the different functions pictures serve in processing textual information (Levin, 1981): decorational – those that bear little or no relationship to the text; representational – pictures that mirror part or all of the text content; organizational – those that provide a structural framework for the text; interpretational – those that help to clarify difficult text, and transformational – pictures designed to improve memory retention of the textual information. Their meta-analysis of empirical studies showed that all of these types of pictures, except for those that are decorational, have moderate to substantial positive effects.

The definition and framework used by Carney and Levin (2002), which is the perspective adopted by the authors of this paper, are narrower than the concept of 'visuals' and 'visualization' in mathematics education. Presmeg (2006) elaborated the current research on visualization and emphasized its role in exploring mathematical ideas and problem solving. These visuals go beyond simply clarifying textual information. In contrast, the sole intended purpose of pictures in this study was to make written mathematics questions potentially more comprehensible for students.

Methods

Research question

Does language simplification or the inclusion of pictures increase the comprehension and performance of Emirati university students on mathematics word problem solving in English?

Participants

Two hundred thirty-five female undergraduate students at Zayed University (ZU), Abu Dhabi campus, participated in this study. The students were in their first or second year of university and were registered in first-year level general education courses, including two mathematics courses on basic data analysis and functions. At the time of the study, this sample represented approximately 21% of the total female population of the general education program on this campus. This study was conducted outside class hours; students were made fully aware that they were not required to participate and that participation or non-participation would not affect their grades.

In order to register in these first-year level mathematics courses, students must have passed a mathematics placement test or a remedial mathematics course. This assures that students have mastered percentage to decimal/ fraction and decimal/fraction to percentage conversions, calculating *percentages of x*, and interpreting problems with terms such as *increased by*, *decreased by*, *discount*, *profit*, *percent change*, etc. Therefore, it was assumed that all participants had the capability to answer percent questions.

In terms of English language proficiency, the students had a wide range of abilities. ZU uses the International English Language Testing System (IELTS) to assess English competence for admission purposes. This system assigns students band scores from 1 to 9, with 1 representing non-users or people with no ability to use the language beyond possibly a few isolated words, and 9 as expert users of English who have a fully operational command of the language (International English Language Testing System, 2014). The participants in this study came from a student body with this profile: mean listening score of 4.97 (range: 3 to 8), mean reading score of 4.75 (range: 2 to 8.5), mean writing score of 5.13 (range: 0.5 to 8), and mean speaking score of 5.72 (range: 2 to 8) (Based on data from all female ZU students who took the IELTS exam from January 2012 to July 2014). As a reference, band 5 represents modest users: those who have partial command of the language, capable of coping with overall meaning in most situations, but who are likely to make many mistakes (International English Language Testing System, 2014).

Instrument

The instrument developed for this study involved two mathematics word problems (see Figure 1 and Figure 2), each followed by a series of questions designed to check the students' comprehension of the various elements of the task (see Table 1 and Table 2). These questions were designed to elicit data that could be gathered from think-aloud interviews but could be administered to a larger number of students. Tables 1 and 2 include the authors' rationale behind the addition of each comprehension question to the instrument. These questions were presented in both English and Arabic. The two tasks were selected based on the appropriateness of their difficulty level and their similarity to some materials students had already seen in their previous mathematics courses.

Figure 1: Word Problem 1, original version ("AED" refers to Emirati currency).

Original Version
Sara is paid commission according to the following scale:
4% on the first AED 10,000 in sales each month
6% on the next AED 12,000 in sales each month
9% on sales greater than AED 22,000 each month
If she sold AED 26,548 in merchandise in one month, what was her commission?

Instrument versions and modification of word problems

The two original word problems were designated to be the control tasks and four other versions were made for each: (1) an Arabic translation, (2) a version where the language was simplified, (3) a version that was made linguistically more complicated, and (4) a version where a picture (a number line or an image of a man on a weighing scale) was added to the original question (see Appendix A, Appendix B). A student volunteer and ZU's Translation Services office translated the two tasks into Arabic; Arabic-speaking faculty checked their accuracy.

Table 1: Comprehension questions for word problem 1, with rationale for each question.

Questions for Word Problem 1	What can be inferred from the student's answer to this question?
1. Is Sara a salesperson or a customer? (Salesperson, Customer) هل سارة هي مسؤولة مبيعات أم عميلة (مسؤولة بيع، عميلة)	Does the student understand the context of the task and Sara's key role?
2. If Sara sells more merchandise, what happens to her commission? (Increases, Decreases) في حال باعت سارة سلعاً أكثر، ماذا يحدث لعمولتها؟ (تزيد، تنقص)	Does the student understand the word "commission", the concept of commission and the relationship of commission and sales?
3. Does Sara sell the same amount every month? (Probably yes, probably no) هل تبيع سارة نفس كمية السلع في كل شهر؟ (على الأرجح نعم، على الأرجح لا)	Does the student understand the dynamics of selling, and that sales in this type of work are necessarily irregular?
4. If she doesn't sell anything, how much is her commission? في حال لم تبع سارة أي سلعة، فماذا تكون عمولتها؟	Does the student understand the concept of commission and the relationship of commission and sales?
5. Would her commission be higher than her sales? (Yes, No) هل تكون نسبة عمولة سارة أعلى من قيمة مبيعاتها؟ (نعم، لا)	Does the student understand the concept of commission and the relationship of commission and sales?
6. How many calculations are necessary to answer this question? (1, more than 1) ما هو عدد مرات العمليات الحسابية المطلوبة للإجابة على السؤال أعلاه (مرة، أكثر من مرة)	Does the student have an idea of the appropriate mathematical strategy to answer the word problem?
7. To calculate the commission, do you need to subtract? (Yes, No) لاحتساب نسبة العمولة، هل ينبغي اللجوء إلى الطرح؟ (نعم، لا)	Does the student have an idea of the appropriate mathematical strategy to answer the word problem?
8. If Sara's sales amount is AED 5,400, do you need to use 6% for your calculations? (Yes, No) في حال بلغت مبيعات سارة قيمة 5,400 درهم، فهل تحتاج الي استخدام 6 % عن الحسابات الخاصة بك؟ (نعم، لا)	Does the student understand the commission payment scheme?

9. If her sales amount is AED 30,000, how much of that gets a 9% commission? في حال وصلت نسبة مبيعات سارة إلى 30,000 درهم، فكم يكون مبلغ عمولتها إذا احتسبت العمولة لها بنسبة 9%	Does the student understand the commission payment scheme?
10. What is her commission? ما هي العمولة التي تحصل عليها سارة؟	Can the student use appropriate strategies to obtain the correct answer to this word problem?
11. Is 4% the same as 0.04? (Yes, No) هل عمولة 4% توازي 0.04؟ (نعم، لا)	Does the student know how to convert percentages to decimals?

Figure 2: Word problem 2, original version.

Original Version

In a scientific study that relates weight to health, people are considered overweight if their actual weight is at least 20% above their ideal weight. If Ali weighs 73 kilos and has an ideal weight of 59 kilos, is he considered overweight?

Table 2: Comprehension questions for word problem 2, with rationale for each question.

Questions for Word Problem 2	What can be inferred from the student's answer to this question?
1.Is Ali's weight greater than the ideal weight? (Yes, No) هل وزن عليّ الفعلي يفوق وزنه المثالي؟ (نعم، لا)	Does the student understand the scenario and the key pieces of information in the word problem?
2. If Ali's weight is 55 kilos, is he overweight? (Yes, No) إذا كان وزن عليّ 55 كلغ، هل يعتبر وزنه زائداً؟ (نعم، لا)	Does the student understand the scenario and the key pieces of information in the word problem?
3. Is it better for Ali to weigh 61 kilos or 73 kilos? (61, 73) هل من الأفضل أن يكون وزن عليّ 61 كلغ أم 73 كلغ؟ (61، 73)	Does the student understand the scenario? Would cultural preferences relating to weight affect the interpretation of the problem?

4. Is everybody's ideal weight 59 kilos? (Yes, No) هل الوزن المثالي عند الجميع هو 59 كلغ (نعم، لا)	Does the student understand the scenario?
5. Is it better to have the ideal weight or be overweight? (Ideal weight, Overweight) هل من الأفضل بلوغ الوزن المثالي أو أن يكون وزنكم زائدا ؟ (مثالي، زائد)	Does the student understand the words "ideal" and "overweight?"
6. How many operations are necessary to answer this question? (1, more than 1) كم عملية حسابية ينبغي القيام بها للرد على السؤال السابق؟ (واحدة، أكثر)	Does the student have an idea of the appropriate mathematical strategy to answer the word problem?
7. Should everybody's excess weight be below 20% of their ideal? (Yes, No) هل ينبغي أن يكون الوزن الزائد عند الجميع اقل بنسبة 20% من وزنهم المثالي؟ (نعم لا)	Does the student understand the premise of the problem? Does the student understand the word "everybody?"
8. Using this problem, can you calculate your ideal weight? (Yes, No) بالاستناد إلى هذه المسألة أعلاه، هل يمكنكم احتساب وزنكم المثالي؟ (نعم، لا)	Does the student understand the premise of the problem?
9. Is Ali overweight? (Yes, No) هل يعتبر عليّ من زائدي الوزن؟ (نعم، لا)	Can the student use appropriate strategies to obtain the correct answer to this word problem?
10 .What percentage is Ali above his ideal weight? كم هي نسبة زيادة وزن عليّ عن وزنه المثالي؟	Can the student use appropriate strategies to obtain the correct answer to this word problem?

Simplification of the word problems was done in a number of different ways based on the taxonomy provided by Martiniello (2008) among others. In the first word problem, the passive voice was replaced

with an active structure: "*Sara sells products…*" instead of "*Sara is paid….*" In order to avoid the potentially confusing lexical item "*commission*," a sentence was added which attempted to clarify exactly what "commission" is, i.e. "*The company pays Sara extra money when she sells more products.*" A subject and verb were added to the scale of rising percentage-based commission: "*She gets 4% extra on the first AED 10,000....*" Finally, the question itself, which could be read as hypothetical, was replaced with a structure indicating possibility, and in addition, vocabulary was simplified and the person herself (*Sara*) re-included rather than the less personal "*she.*" Thus, "*If she sold AED 26,548 in merchandise in one month, what was her commission?*" was modified to "*If Sara sells products with a value of AED 26,548 in one month, how much extra money will the company pay her?*"

The second problem, which also dealt with a percentage calculation, was simplified by altering vocabulary and syntax and adding information that might provide a clearer context. The initial information was also broken into two sentences rather than just one. Thus, the first clause "*In a scientific study that relates weight to health,*" was replaced with the sentence "*A study compares somebody's weight to their health.*" The passive "*people are considered overweight…*" was modified and vocabulary simplified by stating, "*The study says that people are too heavy….*" In order to avoid potential confusion over the expression "*ideal weight*" (ideal for whom?) and also to add a fuller context, the notion of a doctor was introduced. Consequently, the phrase "*… people are considered overweight if their actual weight is at least 20% above their ideal weight*" was replaced with "*The study says that people are too heavy if their actual weight is 20% more than doctors say they should weigh.*"

The more complicated versions of the problems were made by adding longer clauses and sentences, including a higher proportion of less frequently used vocabulary and also by using more complex grammatical structures. Also, superfluous words were added that had no impact on the problem or its outcome. To exemplify this, the first sentence of the first problem with modifications read: "*Working at a large retail outlet with high-end clientele, Sara gets paid a monthly commission by her company.*" Here, the sentence begins with a subject-less participle clause and is followed by less frequently used vocabulary items, some of which are redundant. The subject, "*Sara,*" is introduced in the second clause, but this is immediately followed by the passive, made informal by the use of the auxiliary verb "*gets.*" The potentially confusing item "*commission*" is retained. Similar modifications were used in both the remainder of this problem and also in the second task concerning Ali and his weight.

Procedure

The participants were randomly assigned to the following treatment groups: (1) control (original word problems), (2) Arabic, (3) simplified language, (4) complicated language, and (5) picture plus original. Students were allowed to use calculators. The responses to the questions were analyzed using standard *z*-tests for equality of proportions and other descriptive statistics.

Findings

The analyses reveal that there were almost no differences between the comprehension and performance of the five groups. Table 3 and Table 4 show the percentages of correct and incorrect answers for each comprehension question, for both word problems, and for all treatment groups. What was most evident was that almost no student was able to answer the two mathematics questions (question 10 in Table 3 and Table 4).

Table 3: Percentage of each response for each comprehension question, Word Problem 1.

		Original English (%)	Arabic (%)	Simplified English (%)	Complicated English (%)	Original + Picture (%)
1. Is Sara a salesperson or a customer?	Customer	15.6%	16.7%	8.7%	6.4%	12.5%
	Salesperson (Correct)	84.4%	83.3%	91.3%	93.6%	87.5%
2. If Sara sells more merchandise, what happens to her commission?	Decreases	6.6%	7.1%	4.3%	6.4%	8.3%
	Increases (Correct)	93.3%	92.9%	95.7%	93.6%	91.7%
3. Does Sara sell the same amount every month?	Probably yes	20%	16.7%	17.4%	14.9%	14.6%
	Probably no (Correct)	80%	83.3%	82.6%	85.1%	85.4%
4. If she doesn't sell anything, how much is her commission?	Not 0	42.2%	47.6%	50%	36.2%	45.8%
	0 or nothing (Correct)	57.8%	52.4%	50%	63.8%	54.2%
5. Would her commission be higher than her sales?	Higher	24.4%$_{a}$	47.6%$_{b}$	39.1%$_{a,b}$	42.6%$_{a,b}$	37.5%$_{a,b}$
	Not higher (Correct)	75.6%$_{a}$	52.4%$_{b}$	60.9%$_{a,b}$	57.4%$_{a,b}$	62.5%$_{a,b}$
6. How many calculations are necessary to answer this question?	One	40%	42.9%	39.1%	38.3%	39.6%
	More than 1 (Correct)	60%	57.1%	60.9%	61.7%	60.4%
7. To calculate the commission, do you need to subtract?	No	71.1%	66.7%	63%	66%	58.3%
	Yes (Correct)	28.9%	33.3%	37%	34%	41.7%
8. If Sara's sales amount is AED 5,400, do you need to use 6% for your calculations?	Yes	42.2%	23.8%	26.1%	29.8%	33.3%
	No (Correct)	57.8%	72.2%	73.9%	70.2%	66.7%
9. If her sales amount is AED 30,000, how much of that gets a 9% commission?	Incorrect Answer	91.1%	95.2%	100%	97.9%	93.8%
	8,000 (Correct)	8.9%	4.8%	0%	2.1%	6.2%
* Answer to previous question is AED 2,700 (30,000 x 0.09).	No	75.6%	69%	71.7%	83%	70.8%
	Yes	24.4%	31%	28.3%	17%	29.2%
10. What is her commission?	Incorrect Answer	97.8%	97.6%	100%	100%	93.8%
	1,529.32 (Correct)	2.2%	2.4%	0%	0%	6.2%
11. Is 4% the same as 0.04?	No (Incorrect)	31.1%	28.6%	26.1%	38.3%	22.9%
	Yes (Correct)	68.9%	71.4%	73.9%	61.7%	77.1%

Note. Values in the same row sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column proportions. Tests assume equal variances.

Table 4: Percentage of each response for each comprehension question, Word Problem 2.

		Version				
		Original English (%)	Arabic (%)	Simplified English (%)	Complicated English (%)	Original + Picture (%)
1. Is Ali's weight greater than the ideal weight?	No	14.6%$_{a,c,d}$	29.3%$_{a,b}$	21.4%$_{a,c,d}$	10.5%$_{c}$	29.2%$_{b,d}$
	Yes (Correct)	85.4%$_{a,c,d}$	70.7%$_{a,b}$	78.6%$_{a,c,d}$	89.5%$_{c}$	70.8%$_{b,d}$
2. If Ali's weight is 55 kilos, is he overweight?	Yes	9.8%	12.2%	4.8%	5.3%	8.3%
	No (Correct)	90.2%	87.8%	95.2%	94.7%	91.7%
3. Is it better for Ali to weigh 61 kilos or 73 kilos?	73	12.2%	12.2%	11.9%	7.9%	14.6%
	61 (Correct)	87.8%	87.8%	88.1%	92.1%	85.4%
4. Is everybody's ideal weight 59 kilos?	Yes	14.6%$_{a,b}$	4.9%$_{a}$	7.1%$_{a,b}$	10.5%$_{a,b}$	18.8%$_{b}$
	No (Correct)	85.4%$_{a,b}$	95.1%$_{a}$	92.9%$_{a,b}$	89.5%$_{a,b}$	81.2%$_{b}$
5. Is it better to have the ideal weight or be overweight?	Overweight	7.3%	4.9%	2.4%	5.3%	2.1%
	Ideal weight (Correct)	92.7%	95.1%	97.6%	94.7%	97.9%
6. How many operations are necessary to answer this question?	One	65.9%	68.3%	76.2%	65.8%	58.3%
	More than 1 (Correct)	34.1%	31.7%	23.8%	34.2%	41.7%
7. Should everybody's excess weight be below 20% of their ideal?	No	46.3%	58.5%	61.9%	65.8%	56.3%
	Yes (Correct)	53.7%	41.5%	38.1%	34.2%	43.7%
8. Using this problem, can you calculate your ideal weight?	Yes	73.2%	80.5%	76.2%	81.6%	79.2%
	No (Correct)	26.8%	19.5%	23.8%	19.4%	20.8%
9. Is Ali overweight?	No	41.5%$_{a,b}$	39%$_{a,b}$	28.6%$_{a,b}$	21.1%$_{a}$	47.9%$_{b}$
	Yes (Correct)	58.5%$_{a,b}$	61%$_{a,b}$	71.4%$_{a,b}$	78.9%$_{a}$	52.1%$_{b}$
10. What percentage is Ali above his ideal weight?	Incorrect answer	95%	95.1%	97.6%	100%	100%
	23.73% (Correct)	5%	4.9%	2.4%	0%	0%

Note. Values in the same row and sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column proportions. Tests assume equal variances.

Parallel plots of the proportions of correct answers were created to visually show the similarities between the groups (Figure 3 and Figure 4). Together with the high correlation between the treatments (Table 5 and Table 6), there is strong evidence that the average performances of students, regardless of treatment, were identical. If there were a first-language advantage, then the proportion of correct answers for the Arabic group would have been higher than the original. If language simplification improved the students' comprehension of word problems and their performance, then the simplified language group should have had a higher proportion of correct answers than the original, while the complicated language group should have had a lower proportion of correct answers. Finally, if pictures improved performance, then the proportion of correct answers would have been higher than the original group. All of these hypotheses were found to be false in this experiment. This implies that there was no difference in the effects of the treatments on the students' comprehension of and performance on these mathematics word problems.

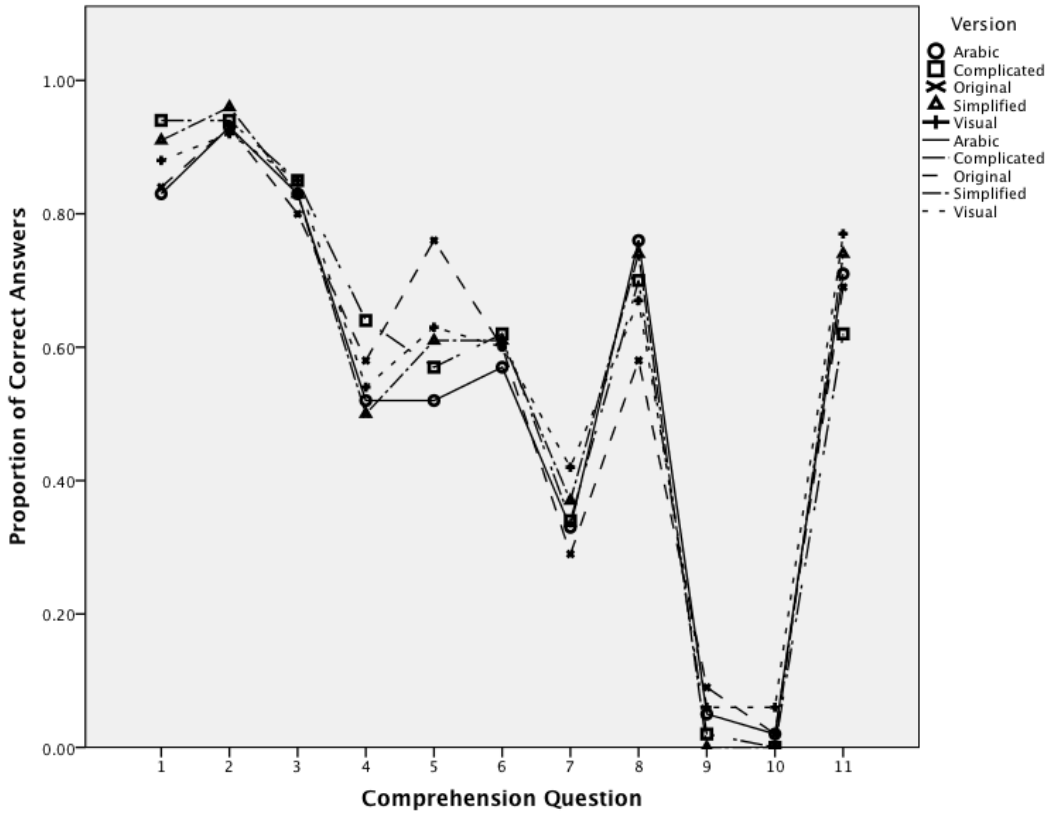


Figure 3: Word problem 1 – proportion of correct responses for each comprehension question.

Table 5: Pearson correlation of proportion of correct responses per treatment for word problem 1.

	Original	Arabic	Simplified	Complicated	Picture

Original	1	0.948**	0.965**	0.962**	0.971**
Arabic	0.948**	1	0.993**	0.980**	0.985**
Simplified	0.965**	0.993**	1	0.981**	0.995**
Complicated	0.962**	0.980**	0.981**	1	0.978**
Picture	0.971**	0.985**	0.995**	0.978**	1

** $p < 0.01$ (2-tailed).

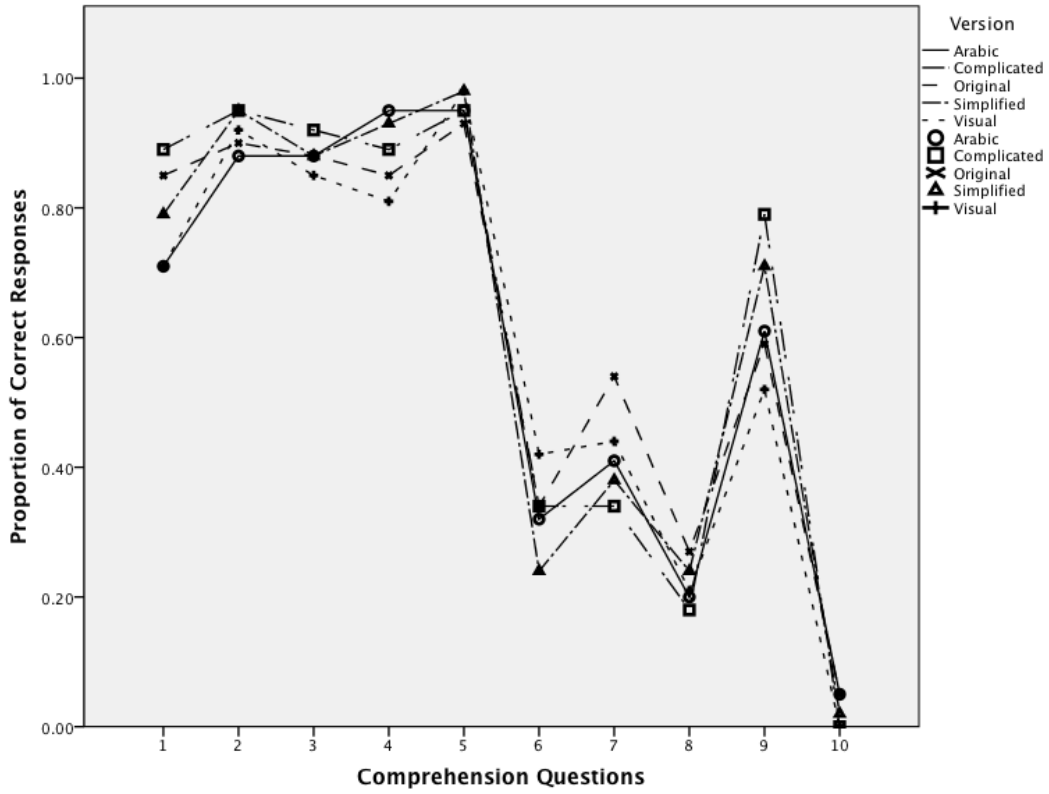


Figure 4: Word problem 2 – proportion of correct responses for each comprehension question.

Table 6: Pearson correlation of proportion of correct responses per treatment (word problem 2).

	Original	Arabic	Simplified	Complicated	Picture
Original	1	.976**	.974**	.966**	.978**
Arabic	.976**	1	.988**	.970**	.979**
Simplified	.974**	.988**	1	.986**	.962**
Complicated	.966**	.970**	.986**	1	.952**
Picture	.978**	.979**	.962**	.952**	1

** $p < 0.01$ (2-tailed).

Analysis of individual comprehension questions and some hypotheses

Although the overall performance profiles for the different groups were similar, analyses on a lower level involving each individual comprehension question revealed some statistically significant differences. For example, there were differences in students' answers on whether Sara's commission would be higher than her sales (see Table 3, question 5); the proportion of correct answers in the original version was higher than in the Arabic version. This might be a case where an English word is more commonly used in everyday language than its Arabic translation.

However, what is more interesting pedagogically are the inferences that can be made by looking at the pattern of student responses (see Tables 1 and 2, column 2). For word problem 1, question 9, "*If her sales amount is AED 30,000, how much of that gets a 9% commission?*" some students answered "2,700" (i.e. they had calculated 30,000 x 0.09). 26 percent of the students provided this answer, but only 2% were able to solve the actual word problem (question 10). This suggests that some students knew how to calculate commission (multiplying the rate by the total sales), but were unable to understand, completely ignored, or failed to correctly utilize the commission scale. The failure to understand the scale is reflected in responses to questions 7 and 8, where most students did not know that the cap of AED 22,000 must be subtracted from AED 26,548 and that the 6% commission is only for sales above the AED 10,000 mark (refer to the original problem, Figure 1). Thus, many students answered that only one operation is necessary to answer the problem (question 6).

The words *commission* (problem 1) and *ideal* may have been difficult lexical items for these students. As was shown in Table 3, students had an incomplete understanding of how commission is related to sales. They knew that the more merchandise is sold, the higher the commission (question 2). However, many incorrectly thought that if Sara does not sell anything, she would still get a commission (question 4). Many students also assumed that commission is higher than sales (question 5). In addition, the proportion of students who answered that commission is higher than sales was higher in the Arabic group than in the original version group. It could be presumed that the Arabic translation of the word *commission* (عمولة) is an uncommon term or perhaps not easily translated. The same could be said for the word *ideal* because there were more correct answers in the complicated English version than in the Arabic version (see Table 4, question 1).

Regarding word problem 2, it could be conjectured that the notion of "*ideal*" is complex in any language, perhaps more so when it is linked to the culturally bound notion of what it means to have an "*ideal weight*." Nonetheless, in response to the question "*Is it better for Ali to weigh 61 kilos or 73 kilos?*" more students chose the lower option, reflecting the view that weighing less is better (question 3). In addition, it could also be inferred that students generally understood the context of the problem: they knew that Ali's weight is greater than his ideal weight (question 1); they understood that if his weight is below the ideal weight, he cannot be overweight (question 2); and they recognized that the ideal weight of 59 kg is only for Ali and not for the general population (question 4). However, many did not fully understand that the 20% cut-off is not just for Ali (question 7) and furthermore, incorrectly believed that anyone's ideal weight can be calculated using the data provided in the problem (question 8). Another possible explanation for question 7 is that they failed to recognize the equivalence of these phrases: "people are considered overweight if their actual weight is *at least 20% above*…" and "Should everybody's *excess weight be below 20% of their ideal?*"

Finally, the picture in word problem 2 may have made the text more confusing. Table 4 shows that more students in the complicated group answered questions 1 and 9 correctly than in the picture group – "*Is*

Ali's weight greater than the ideal weight?" and "*Is Ali overweight?*" Perhaps, the students did not see the picture as an image of an overweight man.

Conclusions

This study presents convincing evidence that suggests that neither language simplification nor pictures automatically improve the comprehension and performance of university-level second-language learners on word problem assessments in English. For the participants in this study, the lexical and syntactic features of the word problems in the tests had little effect on their understanding and ability to answer the question. In addition, evidence suggests that there was no first-language (Arabic) advantage for these students. It could be conjectured that this would be the case for other mathematics assessments taken by Emirati university students with a similar language profile. These findings are in line with previous studies (Kieffer, et. al., 2009) which found no evidence that simplifying the language of mathematics tests had a significant positive effect on scores. Nonetheless, certain lexical items, such as the words *commission* and *ideal*, may still affect students' comprehension without necessarily determining their ability to solve the problem.

These findings have very important theoretical and practical implications that could affect how research on mathematics education in the tertiary levels is framed and how instruction is delivered in globalist classrooms. The initial theoretical position assumed by the authors – that language is simply an agent of problem complexity or an extraneous variable whose effect needs to be minimized in order to improve mathematical performance – is perhaps not the appropriate perspective to adopt. Why did simplifying language or using the native language (Arabic) not increase the chances of higher mathematical performance among students? This appears to run counter to evidence found in the literature, that language and mathematics learning are associated (Solano-Flores, 2010). To explain this paradoxical result, it could be hypothesized that language is not simply a factor that adds to mathematical complexity which needs to be eliminated. Referring back to Solano-Flores' (2010) framework, language is better viewed as a means for understanding or as a resource for knowledge construction. It may well be better to consider a functional view of language, in which the language's influence on mathematical communication and the development of mathematical knowledge is emphasized.

Viewed this way, the relationship of language and mathematics learning might become more evident *while* learning is taking place. If the effects of language on mathematical competency are only assessed after learning has taken place, then the treatments applied to the assessments (language simplification, Arabic, and pictures), by themselves, would not be efficacious. In other words, it is not that language was not a factor in these students' mathematical learning; rather, the use of a second language when they were learning might have already influenced the learning process early on, making most of them incapable of answering the word problems correctly. Furthermore, if language is investigated during the learning phase, then the investigation of the listening and speaking components of language should take precedence over reading, because tertiary level mathematics instruction usually involves lectures and group discussions. All of this implies that more detailed descriptions of how language affects mathematical development inside the classroom are necessary, which further suggest that research methods and designs that are more sensitive to these dynamics, such as qualitative methodologies, need to be used.

As for the practical implications of this study for those teaching mathematics in similar contexts, it could be concluded that linguistic changes in mathematics assessments will not automatically improve student performance on these tests. This is particularly important for instructors in globalist classrooms similar

to the UAE and other Middle Eastern countries. The findings imply that if instructors and professors are determined to improve mathematical competency, which is usually assessed using these tests, then the focus of improvement should be not the tests themselves but other aspects of the learning process. Simply improving the language of the assessments might not produce substantial improvements in grades. It may also be that the reading component of language is not the most significant influencer of mathematics competency for university students.

Further research should focus not only on replicating this study, but on expanding the investigation to include other reading-intensive activities in which students engage, not only in tests but also in the classroom or at home. More importantly, language simplification, the use of visualization, or the use of the first-language should also be investigated during the delivery of the lesson and class discussions, not only while reading but also during lectures and class discussions. Such studies could reveal whether language simplification, pictures, or using the first-language would truly improve students' comprehension of the mathematical text and problems they encounter in their classes.

References

Abedi, J. (2002). Standardized achievement tests and English language learners: Psychometrics issues. *Educational Assessment, 8*(3), 231-257.

Abedi, J., Hofstetter, C. H., & Lord, C. (2004). Assessment accommodations for English language learners: Implications for policy-based empirical research. *Review of Educational Research, 74*(1), 1-28.

Abedi, J. & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education, 14*(3), 219-234.

Abedi, J., Lord, C., Hofstetter, C. H., & Baker, E. (2000). Impact of accommodation strategies on English language learners' test performance. *Educational measurement: issues and practice, 19*(3), 16-26.

Abella, R., Urrutia, J. & Shneyderman, A. (2005). An examination of the validity of English-language achievement test scores in an English language learner population. *Bilingual Research Journal, 29*(1), 127-144.

Austin, J. L., & Howson, A.G. (1979). Language and mathematical education. *Educational Studies in Mathematics, 10*(2), 161-197.

Badri, M., & Khaili, M. A. (2014). Migration of P-12 education from its current state to one of high quality: the aspirations of Abu Dhabi. *Policy Futures in Education*, *12*(2), 200-220.

Barwell, R. (2003). Linguistic discrimination: an issue for research in mathematics education. *For the Learning of Mathematics, 23*(2), 37-43.

Bernardo, A. B. I. (1999). Overcoming obstacles to understanding and solving word problems in mathematics. *Educational Psychology, 19*(2), 149-163.

Bernardo, A. B. I. (2002). Language and mathematical problem solving among bilinguals. *The Journal of Psychology, 136*(3), 283-297.

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*(1), 5-26.

Causapin, M., & Groombridge, T. (2014). *Challenges for Emirati university students in comprehending mathematical text and word problems.* Paper presented at the Frontiers in Mathematics and Science Education Research Conference, Famagusta, North Cyprus.

International English Language Testing System. (2014). *IELTS | Institutions - IELTS band scores*.

Kieffer, M. J., Lesaux, N. K., Rivera, M., & Francis, D. J. (2009). Accommodations for English language learners taking large-scale assessments: A meta-analysis on effectiveness and validity. *Review of Educational Research, 79*(3), 1168-1201.

Levin, J. R. (1981). On functions of pictures in prose. In Pirozzolo, F. J., & Wittrock, M. C. (Eds.), *Neuropsychological and cognitive processes in reading* (pp. 203-228). New York: Academic Press.

Martiniello, M. (2008). Language and the performance of English-language learners in math word problems. *Harvard Educational Review, 78*(2), 333-368.

Ní Ríordáin, M., & O'Donoghue, J. (2011). Tackling the transition: the English mathematics register and students learning through the medium of Irish. *Mathematics Education Research Journal, 23*(1), 43-65.

Presmeg, N. C. (2006). Research on visualization in learning and teaching mathematics. In Gutiérrez, A. & Boero, P. (Eds.). *Handbook of research on the psychology of mathematics education* (pp. 205-235). Rotterdam: Sense Publishers.

Shaftel, J., Belton-Kocher, E., Glasnapp, D. & Poggio, J. (2006). The impact of language characteristics in mathematics test items on the performance of English language learners and students with disabilities. *Educational Assessment, 11*(2), 105-126.

Solano-Flores, G. (2010). Function and form in research on language and mathematics education. In J. Moschkovich (Ed.), *Language and mathematics education: Multiple perspectives and directions for research* (pp. 113-149). Charlotte, NC: Information Age Publishing, Inc.

Verzosa, D. B., & Mulligan, J. (2013). Learning to solve addition and subtraction word problems in English as an imported language. *Educational Studies in Mathematics, 82*(2), 223-244.

Yushau, B. (2009). Mathematics and language: issues among bilingual Arabs in English medium universities. *International Journal of Mathematical Education in Science and Technology, 40*(7), 915-926. http://dx.doi.org/10.1080/00207390903223846

Appendix A

Word Problem 1

A.1 Original Version

Sara is paid commission according to the following scale:

4% on the first AED 10,000 in sales each month

6% on the next AED 12,000 in sales each month

9% on sales greater than AED 22,000 each month

If she sold AED 26,548 in merchandise in one month, what was her commission?

A.2 Arabic Version

(مسألة خاصة بالعمولة المتغيرة مأخوذة من نصوص الجامعة التعليمية)

تدفع عمولة لسارة على حسب المقياس التالي:

٤٪ على أول 10,000 درهم من مبيعات كل شهر

٦٪ على الـ 12,000 درهم التالية من مبيعات كل شهر

٩٪ على المبيعات ذات القيمة الأعلى من 22,000 درهم كل شهر

في حال باعت سارة منتجات بقيمة 26,548 درهم في شهر واحد, فكم تكون عمولتها؟

A.3 Simplified Version

Sara sells products for a company. The company pays Sara extra money when she sells more products.

She gets 4% extra money on the first AED 10,000 of sales each month.

She gets 6% extra money on sales between AED 10,000 and 22,000 each month.

She gets 9% extra money on sales over AED 22,000 each month.

If Sara sells products with a value of AED 26,548 in one month, how much extra money will the company pay her?

A.4 Complicated Version

Working at a large retail outlet that deals with high-end clientele, Sara gets paid a monthly commission by her company. Without accounting for tax deductions, or Health Insurance contributions, she is entitled to commission based on the following:

4% on the first AED 10,000 in sales each month

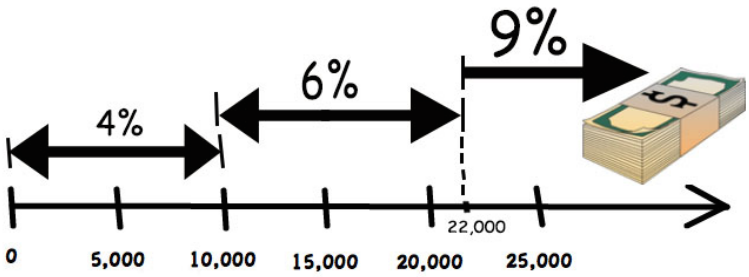
6% on the next AED 12,000 in sales each month

9% on sales greater than AED 22,000 each month

According to the above, what would her commission be if goods sold were worth AED 26,548 during a one-month period?

A.5 Original with Picture Version

Original version of the word problem with diagram below



Appendix B

Word Problem 2

B.1 Original Version

In a scientific study that relates weight to health, people are considered overweight if their actual weight is at least 20% above their ideal weight. If Ali weighs 73 kilos and has an ideal weight of 59 kilos, is he considered overweight?

B.2 Arabic Version

(مسألة مأخوذة من نصوص تعليمية أمريكية)

في دراسة علمية تربط الوزن بالصحة، يعتبر الوزن زائدا اذا كان الوزن الفعلي للشخص يزيد قليلاً عن نسبة 20% من وزنه المثالي، فاذا كان وزن عليّ ٧٣ كيلوغرام، وكان الوزن المثالي بالنسبة له هو ٥٩ كيلوغرام، فهل يعتبر وزن عليّ زائدا

B.3 Simplified Version

A study compares somebody's weight to their health. The study says that people are too heavy if their real weight is 20% more than doctors say they should weigh. Ali weighs 73 kilos, but his doctor says he should weigh 59 kilos. According to the study, is Ali too heavy?

B.4 Complicated Version

A rigorous study conducted last year with a sample population of over 2,600 individuals by the Department of Health attempted to relate a person's actual weight with a theoretical ideal of what their weight should in fact be. The research showed that people, irrespective of age and gender, are considered to be overweight if their actual weight is 20% in excess of what the experts deem to be their hypothetical ideal. Assuming Ali has a

real weight of 73 kilos, and the health experts say he should really have a weight of 59 kilos, would he be considered overweight?

B.5 Original with Picture Version