HOW CAN ONE LEARN MATHEMATICAL WORD PROBLEMS IN A SECOND LANGUAGE? A COGNITIVE LOAD PERSPECTIVE

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ABSTRACT

Language may ordinarily account for difficulties in solving word problems and this is particularly true if mathematical word problems are taught in a language other than one's native language. Research into cognitive load may offer a clear theoretical framework when investigating word problems because memory, specifically working memory, plays a major role in solving problems successfully. The main purpose of this study was to investigate the influence of language when solving mathematical word problems while taking into consideration participant's limited working memory. The participants' main role was to solve word problems in a format that depended on the group they were assigned to. The study utilized a qualitative method approach and involved three phases, a pre-testing, acquisition, and testing phase. Predominant findings from this study show that there was a statistically significant difference between the various groups participants were assigned to.

KEYWORDS

Cognitive load theory, mathematics, second language, and problem solving.

1. INTRODUCTION

The issues involving teaching college level mathematics in the United Arab Emirates (UAE) pose many challenges for teaching faculty and also highlight the need to thoroughly understand these challenges in an attempt to provide instructional guidelines that may help in enhancing student performance scores in mathematics. One of the most obvious challenges would seem to relate to teaching and learning mathematics in a second language. For instance, Emirati students wishing to join Zayed University (ZU) - a federal institution in the UAE- are required to enrol in several mathematics courses. Since the language of instruction is English, mathematic courses are taught in English despite the fact that for the majority of ZU students, English is a second language. To date performance scores have not been very promising and recent investigations have sought ways to improve the learning of mathematical word problems.

2. LITERATURE REVIEW

2.1 Cognitive Load Theory

Cognitive load theory (CLT) may offer a theoretical framework for understanding how materials and the way in which they are presented may in fact impact learning. Cognitive load theory draws on the work of Atkinson and Shriffin (1968), which highlights a limited working memory that can be overloaded based on how information is presented. CLT research has identified a number of instructional designs, two of which are particularly relevant to this study: redundancy effect and modality effect (Sweller, 2004). The redundancy principle suggests that it is more effective to replace multiple information sources that can be understood on their own with just one source of information (see Moussa-Inaty, Ayres, & Sweller, 2012). The modality principle suggests that learning might be enhanced by replacing written explanatory text and another source of visual information with a spoken explanatory text and a visual source of information.

2.2 Mathematics and Language

When solving mathematical word problems students not only need to know the correct mathematical operations in order to answer the tasks at hand, it is also essential for them to be able to successfully deal with the linguistic components - the lexis and syntax. The links between mathematics and language and indeed mathematics as a language have long been studied (see Halliday, 1978; Pimm, 1987). Lexical problems can be compounded by the fact that teachers in the UAE education sectors are from a wide variety of backgrounds (McKinnon, Moussa-Inaty, & Barza, 2014) bringing a number of first languages into the classroom.

3. METHODOLOGY

3.1 Purpose of this Study

The general purpose of the study was to extend the research into the redundancy and the modality effect by specifically examining the impact of spoken and written text in English only vs. spoken and written text in English and Arabic when learning how to solve mathematical word problems.

3.2 Participants

A sample of one hundred and thirty two undergraduate female students from a federal institution agreed to take part in this study (see Table 1). Though the language of instruction was in English, the participants' first language was Arabic, but they were all able to speak and understand English with an average IELTS score of 4.6 for reading and 4.9 for listening, indicating that participants are moderate users of English. All participants were registered in a university college course (MTH 101) that mainly covers secondary mathematics and is specifically designed as a remedial class prior to taking the first year general mathematics courses.

Table 1. Number of participants per treatment group

		n
Groups	Listening Only - English	**18**
	Listening Only - English & Arabic	**20**
	Reading Only - English	**20**
	Reading Only - English & Arabic	**25**
	Reading & Listening - English	**26**
	Reading & Listening - English & Arabic	**23**

3.3 Materials and Procedure

The experiment consisted of three phases, a pretest, an acquisition phase and a testing phase. For the pretest, a set of multiple-choice questions related to finding percentages were asked. For each activity in the acquisition phase both reading and auditory materials were required. For the testing phase, a combination of questions that tested for transfer was presented. To measure cognitive load, a 9-point likert scale was administered after a three phases of the experiment was complete. Students were assigned to one of six treatment groups, namely Read in English (RE), Read in English and Arabic (REA), Listen in English (LE), Listen in English and Arabic (LEA), Read and Listen in English (RLE), and Read and Listen in English and Arabic (RLEA). The format of the materials was presented based on the group the students were assigned to. The analyses focused on aspects of the problems presented that potentially increased cognitive demands for second-language learners.

4. RESULTS AND DISCUSSION

Table 2 shows the mean rank for each treatment group only for those with significance below 0.05.

Table 2. Mean Rank

	Treatment	n	Mean Rank
Acquisition 3&4	Reading Only – English	20	63.53
	Reading Only – English and Arabic	25	69.62
	Listening Only – English	18	49.36
	Listening Only – English and Arabic	20	66.28
	Reading and Listening – English	26	57.77
	Reading and Listening – English and Arabic	23	89.17
	Total	132	
Acquisition Total	Reading Only – English	20	62.08
	Reading Only – English and Arabic	25	69.14
	Listening Only – English	18	47.97
	Listening Only – English and Arabic	20	66.93
	Reading and Listening – English	26	61.50
	Reading and Listening – English and Arabic	23	87.26
	Total	132	
Acquisition MER	Reading Only – English	19	57.61
	Reading Only – English and Arabic	25	54.52
	Listening Only – English	18	99.19
	Listening Only – English and Arabic	19	65.66
	Reading and Listening – English	26	69.62
	Reading and Listening – English and Arabic	22	49.30
	Total	129	
Post-Test 2 Total	Reading Only – English	20	77.70
	Reading Only – English and Arabic	25	65.20
	Listening Only – English	18	69.31
	Listening Only – English and Arabic	20	58.75
	Reading and Listening – English	26	53.75
	Reading and Listening – English and Arabic	23	77.13
	Total	132	

Kruskall-Wallis (KW) test results showed that there was a statistically significant difference between the distributions of Acquisition 3 & 4, Acquisition Total, Acquisition Mental Effort Ratings, and Post-Test 2 Total. For each test with statistical significant differences, pairwise comparisons between treatments were conducted. For Acquisition 3&4, the results for RLEA was higher than LE ($p = 0.003$) and RLE ($p = 0.018$), while without the BC, RLEA was also higher than the rest of the treatments which included RE ($p = 0.013$), LEA ($p = 0.027$), and REA ($p = 0.045$). For Acquisition Total, RLEA was higher than LEA ($p = 0.011$), while without the BC, RLEA was also higher than RLE ($p = 0.015$) and RE ($p = 0.026$). For the Acquisition Mental Effort Rating, RLEA, REA, and RE were all lower than LE ($p < 0.000$, $p = 0.001$, and $p = 0.009$), while without the BC, RLEA was also lower than LEA ($p = 0.006$) and RLE ($p = 0.009$). The extremely low scores overall for Post-Test 2 among students make these last results less certain. Overall, these findings suggest that among the treatment groups, RLEA had the most significant positive impact on student performance during the acquisition phase. On the other hand, LE had the most negative impact.

5. CONCLUSION

The results of this study demonstrated students in a dual mode of instruction outperformed those in a single mode of instruction, but it is important to note the treatment groups that performed the best were engaged in tasks that required *reading* while the treatment group that performed the worst was engaged in tasks that

required *listening*. These results can be explained by considering what Moussa-Inaty, Ayres, and Sweller (2012) called the transient nature of auditory material where additional processing may be required to remember previously heard information. The transient effect of listening can hinder learning since learners have no control over what they hear, which is not the case when learners read. But even though Moussa-Inaty et al. (2012), stressed that for foreign language learners, the simultaneous presentation of spoken and written text should be avoided, in the case of the current study, results showed that students benefited from learning how to solve mathematical word problems when written and auditory materials were simultaneously presented. Results also showed that when solving mathematical word problems, students performed better when two languages were presented simultaneously.

In conclusion, this study supports the use of cognitive load-reducing strategies when learning how to solve mathematical word problems in a second language and this is particularly relevant in countries where English is the language of instruction but not the learners' first language. When teaching how to solve mathematical word problems, the study can confirm that at least some form of reading should be involved and that auditory material should be avoided and not be presented alone as it may impose high cognitive load. The language in which mathematical word problems are presented in this study showed that it did impact student performance, but the unintended added time students in some treatments groups had, may have also been a contributing factor to enhanced performance.

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