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Evaluating the Use of Worked Examples and Problem Solving Methods in Teaching Mathematics for ESL Students at the Tertiary Level

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Keywords

ESL, mathematics teaching methods, problem solving, worked examples, learning mathematics in a second language.

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Abstract

This study presents an overview of the baseline attitudes of King Abdul-Aziz, University, Jeddah, Saudi Arabia (KAU) students to various methods used in mathematics teaching when being taught mathematics in a second language. Seventy male undergraduate students who were enrolled in the first year mathematics subject MATH132 at the KAU were asked to participate in the survey. The results showed that there were differences between the perceived effectiveness of the use of worked examples and problem solving in teaching of mathematics for ESL at tertiary level. Furthermore, the study found that the ESL students who rate their mathematics ability as low prefer to study mathematics using worked examples while the students who rate their mathematics ability as high prefer problem solving or a mixture of problem solving and worked examples. Comments from students who prefer worked examples include their experience of a reduction in anxiety whereas for students who prefer problem solving, comments suggest they experience an increase in confidence. This suggests an effective teaching strategy would be to scaffold from worked examples to problem solving and through this benefitting both weak and more able students.

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1. Introduction

The reality of teaching for many mathematics teachers in countries throughout the world is that they are teaching mathematics to students in English when it is the student's second language. In some countries such as Saudi Arabia, students at university are required to learn mathematics in English, typically their second language. This paper explores issues arising from mathematics teaching and learning in English as Second Language (ESL) context at university level. The intent is to determine which technique, worked examples (WE) or problem solving (PS), is the most effective for ESL students during their mathematical studies. Indications from the field are that worked examples may help such students. Questions that arise as to how helpful worked examples are for these students, and what needs to be done to begin and to continue to expose such students to more structured problem solving, before meeting ill-structured problem solving so that they are able to use their mathematics knowledge in real world applications.

2. Mathematics Education and ESL Students

Historically the learning process of many students in mathematical subjects worldwide is found to be difficult with poor academic outcomes. The ability to read, learn, understand and apply mathematics in a second language is obviously influenced by a variety of language skills. Cassio found a positive correlation between mathematics achievement and second language ability [1]. Students who have English as a second language have an increased level of difficulty as not only do they have the mathematical methods to learn, but also the language barrier is a concern. According to Durkin "Mathematics education begins in language, it advances and stumbles because of languages, and

its outcomes are often assessed in language" [2]. In many countries throughout the world policy dictates that students be taught mathematics in English. The reasons may be economic or political, the need to deal with multiple languages or to gain an advantage in the world economy. Furthermore, the context of the policies may give rise to different issues. Such countries include Malaysia [3] and South Africa [4]. As stated by Barwell [5] perhaps more than any other subject, teaching and learning mathematics depends on language. There are many issues that arise in these contexts:

- Teachers who do not have English as a first language may not be confident teaching in a second language.
- Communicating mathematically in multilingual classrooms may be problematic [4] due to the following linguistic issues:
  - Different usage of language in ordinary English and mathematical English.
  - Differences in the use of formal and informal mathematics language.
  - Differences in procedural and conceptual discourses.
  - Differences in learners' main language and the language and learning of teaching.

In countries where teachers are themselves ESL such as Saudi Arabia, "code-switching", a movement between languages is at times seen as problematic and at other times advantageous [6]. While the Educational Policy in the Kingdom of Saudi Arabia decrees "Arabic is the language of education in all of its stages" [7] the policy of universities in Saudi Arabia is that the language of teaching is English in the subjects such as mathematics, science, and engineering [8]. As a consequence of this change there is potentially an impact on students' achievement and learning [6].

3. Cognitive Load Theory

Along with mathematical issues and problems due to learning in a second language there are also issues arising from the pedagogy of how mathematics is taught. One such issue relates to the cognitive load associated with different learning methods. The term "cognitive load" is used in cognitive psychology to illustrate the load related to the executive control of working memory. Theories contend that during complex learning activities the amount of information and interactions that must be processed simultaneously can either under-load, or overload the finite amount of working memory one possesses. All elements must be processed before meaningful learning can continue. Many would agree that people learn better when they can build on what they already understand but the more a person has to learn in a shorter amount of time, the more difficult it is to process that information in working memory. Consider the difference between having to study a subject in one's native language versus trying to study a subject in a foreign language. The cognitive load is much higher in the second instance because the brain must work to translate the language while simultaneously trying to understand the new information [9].

Worked examples is a technique designed to reduce cognitive load that is caused by some forms of problem solving [10]. With WE teaching techniques, details of the problem statement and all the necessary steps to solve the problem are described. Worked examples direct the attention of a learner to the problem stated, and the steps required to solve a particular type of problem. This reduction in cognitive load should generally make learning easier. According to Jelsma *et al*. [11] learning from worked examples can be more effective in problem solving than learning from solving the actual problem.

Sweller & Cooper [12], Cooper & Sweller [13] studied the use of worked examples and the problem solving method for learning algebra. The study found that the use of worked examples improved the learner's ability to construct a method for solving an algebra problem and also improved their ability to transfer their knowledge to solving related algebra problems. Sweller & Cooper [12] identified that those who learned from worked examples were able to complete the problems faster during a test compared to those who learned only through problem solving.

4. Method

4.1. Questionnaire

A survey questionnaire was used to collect background information about the students in several key areas, including their self-rated ability to do mathematics in English, the current use of learning resources, the use of WE and PS in the subject and their perceived usefulness in learning mathematics. The questionnaire included multiple choice, likert scales and open ended questions.

4.2. Participants

Seventy students enrolled in MATH132 in 2011 were involved in this study, all of whom are studying in their second language (English). Approximately 98 percent of them had an Arabic background and around 95 percent of the students are domestic students. Because of culture and customs in Saudi Arabia, male and female students

are segregated at this university and have totally separate campuses. As a consequence, all the students in this subject are males. The students that participated in the study came from different high school strands which included 58 percent in Mathematics, 30 percent in Science and 10 percent in Arts. Furthermore, around 40 percent have been learning their mathematics in English since high school, Year 11 and 37 percent since Year 12.

5. Impact of Language on Student Learning

Overall there is an association between perceptions of mathematics ability and mathematics ability in English ($\chi^2_4 = 3.2$, $p < 0.0001$). Of the seventy students surveyed, 43 percent (n=30) reported a very poor/poor ability in mathematics and around 31 percent (n=22) reported having a fair/good ability in mathematics. In comparison, when taught in ESL 83 percent (n=58) reported a very poor/poor ability and 17 percent (n=12) fair/good ability in mathematics in English.

It is interesting to look at the students rating their mathematics ability versus the rating of the mathematics ability when learning in English: (refer Table 1). Around 95 percent (n=21) of students who rated their mathematics ability as fair/good, then rated their mathematics ability as very poor/poor when the mathematics subject is taught in English. Also, 61 percent (n=11) of the students who rated their mathematics ability as very good, then rated their mathematics ability as fair/good when mathematics is taught in English. In total, 55 percent (n=39) of students rated their mathematics ability in English lower than their general mathematics ability.

Table 1: Mathematics ability against mathematics ability in English

Mathematics Ability	Mathematics Ability in English		
	Very Poor / Poor	Fair/Good	Total
Very Poor /Poor	30 (100%)	0 (0%)	30 (100%)
Fair/Good	21 (95.5%)	1 (4.5)	22 (100%)
Very Good	7 (38.9%)	11 (61.1%)	18 (100%)
Total	58 (82.9%)	12 (17.1%)	70 (100%)

6. Comparison between Worked Examples (WE) and Problem Solving (PS)

Figure 1 shows students agreed that WE & PS approaches have a positive impact for each of the listed outcomes. For all outcomes except for increasing confidence, WE were more stongly endorsed by students than PS.

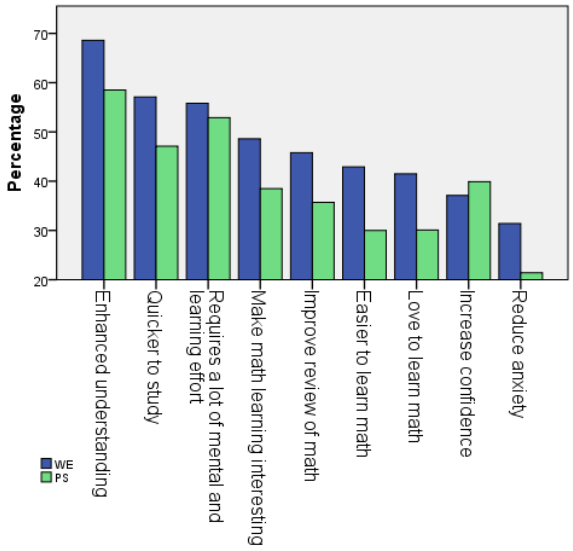

Figure 1: Students' evaluation of using WE and PS in MATH132 (Strongly and Mildly Agree)

The survey asks about the current use of WE & PS given in MATH132. It was revealed that in MATH 132 problem solving (without the use of worked examples as a guide) was used more frequently than worked examples. In relation to the use of these methods, around 70 percent (n=49) of students indicated that having worked examples improved their study compared with only 27 percent (n=19) with PS.

Table 2 shows the breakdown of students' preferred method of study and their self-rated mathematics ability. Thirty-three percent (n=23) of students prefer to study this subject with WE, 50 percent (n=35) with PS and 17 percent (n=12) of students prefer a mixture of WE and PS. Of the students who preferred to study with WE, 65 percent (n=15) rated their mathematics ability as very poor/poor.

Table 2: Mathematics Ability against Preferred Method

Mathematics Ability	Preferred Method			Total
	WE	PS	WE & PS	
Very Poor & Poor	15 (65.2%)	12 (34.3%)	3 (25%)	30 (42.9%)
Fair/good	3 (13.1%)	17 (48.6%)	2 (16.7%)	22 (31.4%)
Very Good	5 (21.7)	6 (17.1%)	7 (58.3%)	18 (25.7)
Total	23 (100%)	35 (100%)	12 (100%)	70 (100%)

Further when examining comments about their reasons for their preferences, thirty percent (n=7) of students who gave preference to WE indicated that WE makes mathematics more interesting compared to 8 percent (n=3) who prefer PS and 16 percent

(n=2) of those preferring a mixture of WE & PS. Also, 14 percent (n=5) of those who prefer problem solving and 16 percent (n=2) of those who like a mixture indicated that PS increases their confidence. It is also worth noting that 21 percent (n=5) of the students who preferred to study only WE commented that it reduced their anxiety. Comments about anxiety were not observed for students who gave a preference of PS or a mixture of PS & WE. Problem solving was seen as building critical thinking by 25 percent (n=9) of students who preferred PS and 25 percent (n=3) of students preferring a mixture. This suggests that WE may help ESL students to learn mathematics possibly due to a reduction in the anxiety which should lead to a reduction in cognitive load.

7. Discussion and Conclusion

This paper reports on the results from the baseline survey conducted in 2011 at KAU University for seventy male students studying MATH132. Based on the survey results 55 percent (n=39) of students rated their mathematics ability in English lower than their general mathematics ability. This is understood to be a consequence of the additional cognitive load of language capability on top of the intrinsic cognitive load in mathematics. The cognitive load is much higher in the second instance because the brain must work to translate the language while simultaneously trying to understand the new information [9].

In terms of responding to different mathematics teaching resources, around 70 percent (n=49) of students were satisfied and agreed that practical worksheets, worked examples and tutorial assignments were useful when they learnt mathematics in a second language. Also, students stated that problem solving was used more frequently than worked examples which has had an effect on their way of learning mathematics. We can see over all but one outcome that more students have agreed that worked examples have a more positive effect on their way of learning mathematics when English is a second language. It is now known that some of the KAU students surveyed like to study their subject with worked examples instead of problem solving. One explanation for this preference can be developed from the cognitive load theory. According to the study by Sweller & Cooper [12], the use of worked examples improved the learner's ability to construct a method for solving an algebra problem and also improved their ability to transfer their knowledge to solving related algebra problems. In conclusion, it is important for teachers to find ways to teach mathematics effectively for their students to learn and understand their subject. These findings support an increase in the use of worked examples for students who are learning mathematics while using a second language.

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