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Exploring Bilingual Arab-American Students' Performance in Solving Mathematics Word Problems in Arabic and English

A Dissertation

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

in

Curriculum and Instruction

Mathematics Education

by

Samar El-Rifai Sarmini

B.S., American University of Beirut, 1990
M. Ed., University of New Orleans, 1996

May 2009

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Samar El-Rifai Sarmini.

In memory of my beloved father, may he rest in peace.

To Mahmoud: my love and soul mate.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God for giving me the strength and perseverance to successfully finish this project. I also thank Him for surrounding me with wonderful caring people who made this journey possible and worthwhile. I am proud to have been able to fulfill my father's aspiration, may God rest his soul. I only wish he is with us here to share the joy of this occasion.

I would like to thank all the students who participated in this study, especially the ones who put serious effort in solving and completing both sets of problems. I also would like to thank their teachers who went out of their way and interrupted their scheduled daily activities to accommodate the requirements of this study. My gratitude goes to the school administration for allowing this study to take place. I especially want to thank the diligence and continuous follow up of Sr. Bilquis Al-Tamimi who made sure the data for this study was in order and that it was sent to me on time.

Data from my pilot study was an essential source for establishing reliability of this current study. Hence, special thanks to all my students at Muslim Academy and members of my community who participated in my pilot study and received me with open hearts and strong support.

Next, I am forever grateful to my committee members' priceless feedback. Nothing is more precious than the gift of knowledge, and for this I sincerely thank you. Your wisdom and invaluable insights helped mold and shape this project.

Dr. Germain, my advisor and major professor, I have been honored to work with you. You truly practice what you teach. There is never a dull moment with you; you always have new ideas that engage your students in new educational endeavors. Your open-mindedness and love of learning are truly contagious. Thank you for the many hours spent in reading and revising this text. Your guidance and leadership have been enlightening.

Dr. Speaker, I am greatly indebted to you for your valuable feedback: organized and straight to the point. Your questions and insights made a major impact on how I made sense of the data. Your list of demands has facilitated shaping and organizing my chapters. I have nothing but the utmost respect for you.

Dr. Thoreson, you have made working with statistics enjoyable and bearable. I have truly enjoyed our discussion sessions in your office. Thank you for providing me with your undivided attention and rich resources.

Dr. Al-Ashhab, you have been a vital part of this study, authenticating and validating the Arabic portion of it. I have managed to keep you busy with correcting student problem sets for both my pilot study and this current study. Thank you for providing me with your time and effort.

I would also like to thank Leslie Cobar who has reviewed the word problems used in this study and has used her own two sons to evaluate the appropriateness of the difficulty level.

This journey has been a long one, but as everyone told me, it truly has been worth it. I would like to thank my colleague, Dr. Thomas Wright, who has

been a true support when things got rough and bumpy. Thank you for acting as a co-rater for the students' solution sets. I am happy that we have helped each other meet the tough demands of the doctoral program. You kept reassuring me that I will meet deadlines, when it seemed I was far from it, and for that I am grateful. I wish you the best.

At the end, I dedicate this work to my husband, Mahmoud; without his support and unconditional love, none of this could have ever been possible. I thank you for not allowing me to quit when things got hectic. When at times I felt floating in the middle of the ocean, you kept pushing me and believing in me until you helped me reach the shore, and for that I am forever grateful. My kids are my real inspiration. Mohammad, Bilal, and Omar: thank you for your prayers and for your patience when your mommy was not around.

My gratitude goes to all the members of my family. In particular, I love you mom and dad for instilling in me the love of learning. You have raised me to have a better appreciation for what is really important in life. I would also like to thank my brother, Naim, and my sisters, Ibtisam and Heyam, for looking out for me and continuously encouraging me. I would also like to give special thanks for my in-laws who played an important role in providing support and a hot meal when things got crazy. Thank you all.

اللهم علمنا ما ينفعنا وانفعنا بما علمتنا وزدنا علما

Oh Lord! Teach us what benefits us, benefit us with what you taught us, and increase our knowledge.

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ABSTRACT

This study aims at answering questions pertaining to the performance of bilingual Arab-American students on solving word problems written in their home and school languages: (1) Does the language in which a word problem is stated have an effect on the performance of the bilingual Arab-American students?; (2) Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems?; and (3) What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic? The study used both quantitative and qualitative methods to analyze these questions.

A total of 173 students from a full-time Islamic school participated in this study: 56 students in fifth grade, 56 students in sixth grade, and 61 students in seventh grade. All students were asked to solve two sets of ten word problems each. The students were randomly assigned to one of four groups.

Results showed that Arab-American students performed significantly better in the English version of the word problems. Arab-American students with higher levels of Arabic proficiency performed better in the Arabic version of the word problems. Students' standardized scores on mathematics problem solving was a significant factor in explaining variances in student performance on both language versions of both sets of word problems. While students'

standardized scores on reading comprehension was a significant factor in predicting the students' performance on the English version of the word problems, students' final average in the Arabic subject was a significant factor in predicting students' performance on the Arabic version of the word problems.

Differences and similarities emerged in the problem solving processes of Arab-American students solving the word problems in either English or Arabic. Some students found statements involving double comparisons, problems with hidden information, and problems that required multi-step solutions or thinking backwards to be problematic in both language versions of the problems. Difficult vocabulary was especially problematic for students when solving the Arabic version of the word problems.

KEYWORDS: Arab-Americans, bilinguals, language minority students, Arabic language, math problem solving, word problems, multicultural education, student achievement.

CHAPTER ONE

INTRODUCTION

This study investigated the effect of student comprehension levels in the home language (Arabic) and the language of instruction (English) on their abilities to solve mathematical word problems presented in both languages. The study also investigated whether students with higher levels of comprehension in the home language tend to perform better on either language versions of the word problems. The study finally explored any common trends in student processings of both language versions of the problems.

This chapter describes the background of the study, the theoretical framework, the purpose of the study, the research questions, and the significance of the study. A list of definitions of terms, limitations and delimitations, and the organization of the study are included at the end of the chapter.

Background of the Study

Many studies have shown that students' difficulties and poor performance in mathematical problem solving are more of a linguistic nature rather than intellectual or cognitive (Bernardo, 2002; Dawe, 1983; De Avila & Duncan, 1985, Mestre, 1988). This influence of language on problem solving skills is particularly salient for students who are bilingual and are considered to be language-minority students. Cuevas (1984) points out that a major source of underachievement in school is students' inability to understand the language of instruction. Khisty (1995) makes it clear that language is crucial in the teaching and learning process by which meanings are developed and shared within the classroom. Aiken (1972) reports that reading comprehension highly correlated with problem solving abilities and that difficult vocabulary and syntax continue to be an impediment to successful problem solving.

Students who are not native-born English speakers are often labeled as Limited English Proficient (LEP) or language minority students. Such educational labels tend to call attention to what students cannot do. In addition, the term "minority" tends to carry the meaning of inferiority, even though it is used in reference to the numerical status of these particular students. This sensitivity towards labeling has been reflected in refraining from referring to people as "disabled" or "handicapped", but rather as people who are "physically challenged" or "differently abled", thus, steering focus away from their limitations and viewing them in terms of their capabilities (McLeod, 1994). Negative labels may color the treatment of students who lack English fluency and enhance false assumptions that somehow students who cannot speak English proficiently also lack the intellectual capacity for high level academic achievement (McLeod, 1994).

The National Assessment for Educational Progress (NAEP) reported that, in 2003, 51% of Limited-English-proficient (LEP) students in 4^{th} Grade and 74% in 8^{th} Grade performed below the Basic level nationwide, while only 9% of LEP students in 4^{th} Grade and 5% in 8^{th} Grade performed at or above the

Proficient level (National Center for Education Statistics [NCES], 2003). Compare these percentages to 24% of public school students nationwide in 4th Grade and 33% in 8th Grade performing at below Basic level; while 31% in 4th Grade and 27% in 8th Grade performing at or above Proficient level. Of the ELL students in grades 4 and 8, 44% (7% less from 2003) and 70% (4% less from 2003) performed below the Basic level nationwide, respectively. Of the ELL students in grades 4 and 8, 13% (4% more than 2003) and 6% (1% more than 2003) performed at or above the Proficient level, respectively. On the other hand, 16% of non ELL public school students in 4th Grade (8% less than 2003) and 27% in 8th Grade (6% less than 2003) performed at below Basic level; while 42% in 4th Grade (11% more than 2003) and 33% in 8th Grade (6% more than 2003) performed at or above Proficient level. ELL students have shown slight improvement in 2007, compared to 2003; however, public school students have shown greater improvement, especially for those performing at or above Proficient level (NCES, 2007).

Theoretical Framework

In an attempt to understand the low academic achievement of students from non-English language backgrounds, the educational status is analyzed from two different approaches. The traditional approach focuses on the inner abilities of the students, thus emphasizing the psychological aspect of learning, whereas the more contemporary approach shifts attention to the conditions of learning in a sociological framework (McLeod, 1994). The traditional approach is a psychologically based model that sees language as the main obstacle to success, and therefore promotes programs that teach English as a second language as the means to help these students achieve success (McLeod, 1994). The goal is to enable students to become more acceptable in the mainstream society by overcoming the language barrier and helping non-English speakers to become better English speakers (McLeod, 1994). This approach focuses more on imitating already successful groups, hence ignoring the emotional and identification aspects of second language learners (McLeod, 1994). On the other hand, the sociological approach seeks to achieve parity through accepting the non-English speakers into the mainstream society as he or she is, without sacrificing diversity or demeaning any particular group. Identifying non-English speaking students as members of a subordinate group is the main obstacle these students face, not the lack of language skills (McLeod, 1994). If treatment of these students in the day to day classroom activities is ensured to be fair and just, then the end goal of improving their achievement levels will naturally occur as a result (McLeod, 1994).

Both approaches agree on the need to achieve parity between the level of achievement of students from non-English backgrounds and native English speakers. However, they disagree on how to achieve this goal (McLeod, 1994). As these two approaches converge, a new model of teaching emerges that embodies the strengths of both models and tackles shortcomings and oversight present in either. This new model recognizes the importance of both cognitive and socio-emotional factors in the learning process of non-English speaking students (McLeod, 1994).

Purpose of the Study

The purpose of this study is to investigate the performance of Arab-American students when solving mathematics word problems in Arabic and English. Students who participated in this study were mostly non-native English speaking students sharing similar cultural background where the home language is non-English and mostly Arabic. The purpose of this study is to provide a source of input on how this particular group of bilingual students performs on mathematical problem solving when problems are presented in their home language (Arabic) or in their language of instruction (English). This study explored the effect of students' comprehension levels in the Arabic and English languages on their mathematical problem solving abilities.

Research Questions

This study aims at answering the following questions for Arabic speaking students who are literate in both English and Arabic:

1. Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students? Specifically, is there a difference in the performance of Arab-American students when solving word problems in English compared to solving word problems in Arabic?

2. Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems?
3. What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic?

Significance of the Study

There has been growing interest in the effects of bilingualism on the students' cognitive abilities; however, the majority of research has focused on Hispanic students and other minorities, overlooking the Arabic speaking population. This study adds to the existing body of research on bilinguals' performance in mathematical problem solving through its attention to Arab-American students. The lack of research on this particular student population makes this study exploratory in nature and an important first step setting direction for future studies.

Definition of Terms

The following terms are defined in reference to their use for the purpose of this study:

Language proficiency vs. verbal ability: the term language proficiency is used to refer to language skills of persons who do not exhibit native-like skills, while the term verbal ability is used to refer to a continuum of verbal skills observable in native speakers (Duran, 1985).

ELL: English Language Learners.

NEP: Non-English Proficient.

LEP: Limited English Proficient.

L1: first language which refers to the home language.

L2: second language which refers to the school language.

Semilinguals: Students who possess less than native-like skills in both languages (Cummins, 1979).

Fully bilingual: Students who possess native-like skills in both languages (Cummins, 1979).

Arab-American: An Arab-American is a person who resides in the United States and holds an Arab cultural and linguistic heritage. For the purpose of this study, students are referred to as Arab-Americans because their home language is Arabic and they are currently living and studying in the United States. The term Arab-American does not convey any indication of the student's proficiency in either the Arabic or the English languages. In fact, Arab-American students participating in this study include students that can be described as ELL, NEP, LEP, semilinguals, and fully bilinguals. They are considered to be language-minority population. SAT reading comprehension is the measure that was used in this study to differentiate between the levels of English proficiency of these students.

Stanford Achievement Test, tenth edition: The Stanford Achievement Test (SAT) is a standardized test that measures student achievement in reading, language, spelling, study skills, listening, mathematics, science and social science for all grade levels. For the purpose of this study, only reading comprehension and mathematics problem solving categories within the SAT test were used to measure students' proficiency in the English language and ability in mathematical word problem solving.

Arabic final average: the overall average in the Arabic subject given by the school at the end of the academic year. This grade acted as a general measure of Arabic competency of the students participating in this study.

Linguistic distance hypothesis: The differences between semantics, functions and status of languages are referred to in sociolinguistic theory as the linguistic (language) distance (Halliday, 1975).

Cognitive constructivism: Cognitive constructivism explains how learners adapt and refine mental structures that are viable and reflective of one's personal experience (Windschitl, 2002).

Social constructivism: Social constructivism views knowledge as the product of the individual's participation in meaningful activities with others, where much emphasis is placed on communication and negotiation within a mathematical community of learners (Noddings, 1990).

NCTM: the National Council for Teachers of Mathematics is an organization of mathematics educators and administrators who embarked on a mission to drastically improve mathematics education in the United States and Canada.

Equity: Equity as defined by NCTM does not translate to providing all students with identical instruction, but rather making practical and realistic adjustments to instruction so that all students have equal access to success.

Limitations and Delimitations of the Study

This study has been conducted in a full-time Islamic school in the Eastern region of the United States. The population of this study consisted of 173 students from grades 5, 6, and 7. The size of the study sample is relatively small. I used the final yearly average for the Arabic subject given by the school due to the lack of standardized testing in the Arabic subject. While this average provided an overall measure of students' level of competence in the Arabic language, it did not provide a specific measure of the level of comprehension of the student in the Arabic language.

This may limit the generalizability of the findings of this study to students who are Arab-American enrolled in full-time Islamic schools in the United States.

Chapter Summary

Many students, including Arab-Americans, struggle in mathematics. There is a lack of research on exploring factors that might affect Arab-American students' performance in mathematics, particularly in solving word problems. Based on my literature review, many studies found that limited proficiency in the language of mathematical instruction contributed to difficulties faced by bilinguals, especially when the language of instruction of the mathematics was in their weaker language (Aiken, 1972; Bernardo, 1999; Cuevas,1984; Dawe, 1983; De Avila & Duncan, 1985). This study goes beyond investigating the relationship between students' linguistic proficiency, the language of the mathematical word problems, and the students' mathematical problem solving abilities. The students' individual solutions have been carefully studied to detect any patterns or mistakes specific to the Arabic version of the word problems.

Organization of the Study

This study is organized into five chapters that present literature and research results on the influence of language on bilingual students' processing of mathematical word problems.

Chapter I describes the background of this study, the theoretical framework, the purpose of this study, the research questions, and the significance of the study. A list of definitions of terms is included explaining the context in which these terms will be utilized within the study. At the end of this chapter, a limitations and delimitations section followed by an overview of the organization of the study is included.

Chapter II contains a review of the literature pertaining to this study. The chapter begins with an overview of the constructivist theory and then presents NCTM's goals and achievements focusing on issues of equity and cultural diversity in relation to bilingual students. A description of factors affecting the quality of acquiring a second language and a detailed account of Cummins theory on how bilinguals can achieve cognitive competence follows. Finally, a discussion of how knowledge of more than one language relates to students' performance in mathematics together with an account of findings from several studies on bilingual students' performance on mathematical problem solving follows.

Chapter III describes the methodology of this study. It begins with a reference to the purpose of the study and the research questions. This chapter includes a detailed description of the procedures for conducting the study, the sample population, instrumentation, the research design, the data analysis procedures, and research issues, such as reliability and validity of the study.

Chapter IV presents the findings of this study. This chapter begins with the results of the quantitative statistical analysis from running descriptive statistics, correlations, MANCOVA, MANOVA, a multiple regression, and finally, a simple regression followed by a multiple regression. The second part of this chapter reports the results of the qualitative analysis of student word problems processing for each problem in both sets.

Chapter V, the final chapter, ends with relating the findings of this study to the research reported in the literature review. The chapter ends with implications for teaching and implications for further study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This literature review begins with an overview of the theoretical framework guiding this study, namely the constructivist theory. This leads into presenting the contributions of NCTM in the advancement of the mathematics education with special attention to its first principle of equity and how it impacts the mathematical education of students with diverse cultural and linguistic heritage. I then describe the relationship between bilingualism and cognitive achievement, as well as factors affecting the quality of acquiring a second language. Then, a detailed account of Cummins theory that shows the importance of continually developing the first language in order for bilinguals to attain cognitive benefits follows. Finally, a discussion of how knowledge of more than one language relates to students' performance in mathematics follows, along with an account of several studies' findings with respect to bilingual students' performance on mathematical problem solving.

Theoretical Framework

Constructivist Theory

Constructivism is the basis for progressive pedagogy (Windschitl, 2002). From the historical perspective, constructivist movement is in many ways similar to earlier progressive movements that advocated a shift from teacher centered to child centered instruction. Both encouraged teaching for conceptual understanding rather than factual memorization (Windschitl, 2002). Early attempts to reform were reported as early as the late 1800s and included taking students on fieldtrips to the countryside with the intent of teaching them geography in context (Windschitl, 2002). Other attempts included adapting the curriculum to the needs and interests of the students as means of enabling students to become autonomous learners (Windschitl, 2002), self-motivated and active participants in the learning experience.

Ernst von Glasersfeld (1990) derives the following basic principles of constructivism from Jean Piaget's writings whom he and many others considered to be the great pioneer of the constructivist theory of knowing:

1. Knowledge is not passively received either through the senses or by way of communication. Knowledge is actively built up by the cognizing subject.
2. (a) The function of cognition is adaptive, in the biological sense of the term, tending towards fit or viability;

   (b) Cognition serves the subject's organization of the experiential world, not the discovery of an objective ontological reality (pp 22-23).

Through actions and reflection on actions, individuals construct their own reality which is viable within the realm of their experience (Steffe & Kieren, 1994). Moreover, students' constructed knowledge is not considered a mirror of an objective/existing reality that lies beyond them (Steffe & Kieren, 1994), but rather the conceptual means through which individuals make sense of their own experience (von Glasersfeld, 1990).

It was Piaget's cognitive development psychology, and not his epistemology, that greatly influenced the constructivist thought (Steffe & Kieren, 1994). Both Piaget and Kant made a distinction between empirical knowledge and logico-mathematical knowledge (Noddings, 1990). However, while Kant viewed cognitive structures as innate, Piaget believed that they were products of development (Noddings, 1990). Similarly, while Chomsky viewed the linguistic structures of mind to be innate, Piaget maintained that the development of certain logical structures through the coordination of action preceded the construction of linguistic structures and made them possible (Noddings, 1990). Both would agree that cognitive structures are themselves products of continued active construction (Noddings, 1990). Constructivism is thus a combination of a process of assimilation in which knowledge is created, and a process of accommodation in which existing constructs are continually revised and modified based on new experience (Noddings, 1990).

Based on Piaget's logical structures and emphasis on experience in constructivism, children are ready to learn fundamental structures of mathematics through working with physical materials (Steffe & Kieren, 1994). Cognitive research has shown that learners' mathematical thinking progress from the concrete to the abstract (Baroody & Ginsburg, 1990). Hence, a direct application of the Piagetian theory is the heavy use of manipulatives in teaching; the difficulty, however, lies in providing students with a meaningful purpose to engage them in the learning process (Noddings, 1990). The underlying principle of constructivism is that understanding cannot be imposed upon the learner (Baroody & Ginsburg, 1990). Children, like adults, will usually engage in the learning process when they are presented with a novel task of medium complexity that triggers their interest or arouses their natural curiosity (Baroody & Ginsburg, 1990). Vygotsky (1978) referred to the distance between the learner's current level of knowledge and the attainable level of knowledge within reach of the learner as the zone of proximal development (ZPD). Within this ZPD, children are constructing knowledge through problem solving, collaboration, and social interaction In his own words, Vygotsky (1978) defines ZPD as "..the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (p. 86)." A main source for learning difficulties is the gap between formal instruction which is usually abstract and the child's existing knowledge of mathematics which is usually concrete and informal (Baroody & Ginsburg, 1990). When formal instruction is disconnected from the students' existing knowledge and the learning tasks are either too complex or too repetitious and redundant, students will quickly lose interest because they either are not yet ready to learn the material or it makes little or no sense to them (Baroody & Ginsburg, 1990). Polya (1963) acknowledges that abstractions are important in the study of mathematics, however all means should be taken to make them more tangible and accessible for the students. Hence, implications for successful teaching are: to develop diagnostic teaching strategies in the zone of current knowledge; to progress to the zone of proximal development through the use of authentic activities such as problem solving; and to reshape the roles of the teacher and the other learner, the more capable peer (Harland, 2003). A key to successfully diagnosing the current level of knowledge and progressing through the zone of proximal development is to reflect critically about learning (Harland, 2003). Furthermore, authentic activities are essential components for establishing the best environment for learning (Harland, 2003) which are the opposite of the 'busy work' described by Dewey (1938) as "something that has the semblance but not the substance of scientific activity." (p. 108)

Constructivists propose that all mental activity is constructive, even in passive learning situations that involve drill and practice or listening to lectures (Windschitl, 2002; von Glasersfeld, 1995; Noddings, 1990). So, instead of debating on whether a learning situation is constructive or not, some theorists suggest differentiating between "strong" acts of construction and "weak" ones (Windschitl, 2002; Noddings, 1990). Connecting new information with existing concepts to form internally coherent and meaningful body of knowledge that can later be used to further construct new knowledge reflect "strong" acts of construction (Windschitl, 2002). On the other hand, "weak" acts of construction usually occur through memorization or recollection of pieces of information that are disconnected from existing knowledge

(Windschitl, 2002) and have no practical application to the knower (Noddings, 1990).

Types of Constructivist Learning

Some theorists emphasize the cognitive process as constructivist learning; others emphasize the social processes, depending on whether the focus is the individual as the learner, or as the social co-constructor of knowledge (Windschitl, 2002). Cognitive constructivism explains how learners adapt and refine mental structures that are viable and reflective of one's personal experience (Windschitl, 2002). Focus is on studying and explaining the individual's ability to use tools, information resources and input from other individuals to solve problems that arise in the learning process while maintaining and refining ideas that are reasonable to the learner (Windschitl, 2002). The backbone of the process of construction is for the learner to develop personal autonomy (Confrey, 1990). Hence, as teachers, we provide the learner with the lens and the tools to make sense of the world and be able to reflect on those lenses to further develop their cognition (Confrey, 1990). Social constructivism, on the other hand, views knowledge as the product of the individual's participation in meaningful activities with others. Much emphasis is placed on communication and negotiation within a mathematical community of learners (Noddings, 1990). The use of small groups in cooperative learning enables children to gradually internalize the talk that occurs in group interactions (Vygotsky, 1978). They engage in task-oriented dialogue (Windschitl, 2002) during which they begin to question each other's reasoning and challenge each other while at the same time monitoring their own mental processing until they reach consensus (Noddings, 1990) and come up with "shared constructs". Some scholars offered a way of combining the cognitive and social constructivist perspectives by claiming that "knowledge is personally constructed and socially mediated" (Windschitl, 2002). Each individual makes sense of their own personal experience within the constraints of the social interaction through collaboration and communication with other members of the social group to achieve a fit and a consensus within the domain of the social environment (von Glasersfeld, 1990).

NCTM and Constructivism

The business community is always on the lookout for employees who can think creatively, can identify and solve problems, are flexible and able to meet the ever changing work demands, and can work collaboratively with others to produce complex and sophisticated products (Windschitl, 2002). Mathematical competence has always played an important role in opening doors for more productive futures. Realizing that, and the need for continually improving the quality of mathematics instruction to remain competitive with other countries, the National Council for Teachers of Mathematics (NCTM) embarked on a mission to drastically improve mathematics education in the United States and Canada. Beginning in 1989, NCTM published several documents articulating goals and regulations for both teachers and policymakers with respect to curricula, teaching, and assessment. The latest of those documents is the *Principles and Standards for School Mathematics*, published in 2000, which describes the basic skills and understandings necessary for students to be proficient and competent in the twenty-first century. The document is divided into sections highlighting:

(1) The Principles: Principles deal with broad mathematical issues, mainly: equity, curriculum, teaching, learning, assessment, and technology. These principles lay the foundation on which educators could base their decisions related to school mathematics.

(2) The Standards: Standards consist of a total of ten comprehensive goals: five of which discuss instructional goals in the content areas of number and operations, algebra, geometry, measurement, and data analysis and probability; the other five describe procedural goals in problem solving, reasoning and proof, connections, communication, and representation. The ten Standards are discussed in detail including a set of expectations specific to each of the four grade bands: from prekindergarten to grade 2; grades 3 to 5; grades 6 to 8; and grades 9 to 12. Discussion of the issues pertaining to the practical applications of the Principles to help make the vision set by NCTM a reality is included.

Consistent with the theory of constructivism, NCTM (2000) maintains that "students learn more and better when they take control of their own learning. (p. 5)" Making conjectures, experimenting with various approaches to solving problems, constructing mathematical arguments and responding to others' arguments, characterize an active learning environment advocated by NCTM (2000). Problem solving is considered to be a goal as well as a means of learning mathematics. Through problem solving, students build new mathematical knowledge, apply and adapt a variety of appropriate strategies to solve problems while monitoring and reflecting on the process (NCTM, 2000).

In mathematics education, acknowledging the learner as an active knower implies a way of teaching where teachers who embrace the constructivist philosophy act as agents of change rather than transmitters of knowledge (Noddings, 1990). Their aim should include teaching students how to think for the purpose of solving problems by utilizing formal thought processes, such as inductive and deductive reasoning, as well as informal ones, such as making educated guesses about the results of the problem before actually solving the problem (Polya, 1963). Students learn mathematics most efficiently through guided discovery, meaningful application, and problem solving rather than imitating teacher's manipulation of formal symbols through worked out examples and preset algorithms (Goldin, 1990). Polya (1963) identifies three principles of learning:

1. Active learning: "The best way to learn anything is to discover it by yourself." Hence, allowing students to discover the major concepts of the lesson and to establish the mathematical relationships by themselves make the learned information more accessible for future use.

2. Best motivation: Allowing students to formulate their own problems requires more insight and originality than working on the solution, and usually motivate them to work harder to solve the problem. A desirable attitude of the mind to instill in the students would be to encourage them to guess the result before actually solving the problem, hence, following the example of real life scientists.
3. Consecutive phases: Learning begins with (1) exploration and perception through manipulating and experiencing with concrete objects; (2) then formalization to a more conceptual level that involves the use of terminology, definitions, and proofs; and (3) assimilation, where the learnt material is mentally digested and incorporated within the larger system of knowledge leading to higher generalizations on one hand and practical application on the other.

Constructivist teachers build their instruction on students' current knowledge. Because students learn by connecting new ideas to prior knowledge (NCTM, 2000), such teachers are aware of what children bring to the learning situation and they continually evaluate growth in students' understanding through observing, questioning students' solutions and listening to students' interacting with each other (Steffe & Kieren, 1994). A constructivist teacher is more interested in learning how students developed their solution rather than being presented with a faultless product (Noddings, 1990). Hence, part of the effort of the constructivist teacher is to help students make their conceptual models explicit through reflection and communication in order to overcome misconceptions about the students' ways of perceiving an idea, (Confrey, 1990). A constructivist teacher challenges students' existing ideas and presents them with problems that encourage students to engage in discussions utilizing new ideas in different contexts (Windschitl, 2002). They encourage students to discover that various roads might lead to the intended solutions or instructional endpoints (Noddings, 1990). In ideal problem solving situations, teacher's input and guidance should be given only if necessary, so that students don't become preoccupied with trying to fulfill or discover the teacher's expectations and intentions (Noddings, 1990).

NCTM and Equity

The NCTM's *Principles and Standards* (2000)had a profound influence on the reform in mathematics education. NCTM acknowledged that among the issues that have been ignored in the teaching and learning of mathematics were considering the contribution of the student cultural experiences, social background, and the effect of student gender on their learning. In adherence to the importance of cultural heritage, several writers have written books or articles connecting a particular culture to mathematics. Many of Ladson-Billings (1995a, 1995b, 1997) work focus on culturally relevant strategies for teaching African-American students mathematics and other subjects. Several books by Zaslavsky (1994, 1996, 2003) describe different mathematical activities or games that are practiced by diverse cultures in distinct parts of the world. Other writers use a multicultural perspective to provide lenses from which diversity can be appreciated (NCTM, 1997; Nelson, 1993). Germain-McCarthy and Owens (2005) provide case studies of teachers engaging students in a learning environment that is relevant to the student cultural backgrounds and is in accordance with NCTM recommendations and standards. Teachers portrayed use problems or situations that have a cultural connection to classrooms of African-American students, Muslim Arab-American students, Euro-American students, Haitian students, Hispanic students, and native-American students. In this book, the researcher of this study is profiled in a lesson to a group of Arab-American fifth grade students focusing on Islamic inheritance laws as a motivation for teaching multiplication of fractions (Sarmini, 2005). The lesson made connections to the important historical mathematician, Al-Khawarizmi and implemented the use of both Arabic and English languages to show how the terms 'algebra' and 'algorithm' originated from the Arabic terms. The lesson touched on how the Islamic inheritance law is related to the general inheritance laws found in the American society.

Such connections address concerns reflected in a statement issued by NCTM in September of 2008 declaring its position on students who speak a first language other than English or have related cultural differences:

> Every student's cultural heritage should be accepted and celebrated for the diversity that it brings to the learning environment. Expanded opportunities should be available to English language learners (ELL students) who need them to

develop mathematical understanding and proficiency.

Mathematics teachers should have knowledge of content and pedagogy that support ELL students, including an understanding of the role of the first language. (p. 1)

The first principle set by NCTM in the *Principles and Standards for School Mathematics* highlights the vision for a more competitive future: “Excellence in mathematics education requires equity – high expectations and strong support for all students.” Equity as defined by NCTM does not translate to providing all students with identical instruction, but rather making practical and realistic adjustments to instruction so that all students have equal access to success. In order to achieve educational equity, NCTM sets general guidelines in order to achieve educational equity:

1) Equity requires high expectations and worthwhile opportunities for all (p. 12, NCTM 2000). Students who are not native speakers of English, who live in poverty, who are females or classified as nonwhites, and who have disabilities have all been victims of low expectations which had a detrimental effect on their own confidence to succeed in mathematics. Teachers' awareness of this issue, purposive effort to provide steady support to *all* students, and high-quality mathematics instruction play an important role in ensuring students excelling in mathematics.
2) Equity requires accommodating differences to help everyone learn mathematics (p. 12, NCTM 2000). Additional assistance may be needed

for some students in order to meet high mathematics expectations, such as students who are not native speakers of English.

3) Equity requires resources and support for all classrooms and all students (p. 13, NCTM 2000). Technology can play an important role in capturing and maintaining student interest and providing individualized instruction for students who need the extra practice or instruction. Moreover, it may provide students with intellectual resources and a link to the global community of mathematics learners and allow them to engage in collaborative projects with other schools nationwide or worldwide.

Schools and teachers should make content more accessible in a second language as well as find ways to implement culturally relevant pedagogy in teaching mathematics in order to properly serve ELL students (NCTM, 2008). Since communication is underscored in the *Principles and Standards for School Mathematics* (NCTM, 2000) "as an essential part of mathematics and mathematics education", it is critical that teachers provide appropriate support and encouragement for all students, especially ELL students, to speak, write, read, and listen in mathematics classes (NCTM, 2008). Since mathematics is a specialized language with its own grammar and vocabulary, students need to engage in using "the language of mathematics to express mathematical ideas precisely" (NCTM, 2000). Through communication, students learn to articulate their thinking and as they listen to their peers' explanations, they learn to evaluate and build on each others' arguments. A major benefit to communication is exploring problems from multiple perspectives which help sharpen the participants' thinking and reasoning skills.

Recognizing the importance of problem solving as a goal as well as a means of learning mathematics, I was interested in investigating Arab-American students solving word problems in both their home language as well as the language of instruction. When formulating the word problems for each set, special attention was given to choosing a level of difficulty appropriate for students in grade 5 through 7. The numbers used in the word problems were at a difficulty level appropriate for a fifth grader to handle, but not too easy for a seventh grader. The complexity of the word problems was within reach of the students. In order to trigger their interest, the content of the word problems were geared to reflect the students' own cultural experience and social values. Based on NCTM's recommendations to establish equity for ELL students, Arabic may play an important role in supporting the teaching of Arab-American students and in helping make excellence more accessible.

Language and Performance

Importance of Language

Misconceptions about the central role of language in the educational development of bilinguals might prompt some teachers to ask parents of minority language children to avoid using their first language in communicating with their children at home in hopes of helping them become fully proficient in their second language (L2), in this case English, and minimizing confusion of continuous switching between their first language (L1) and L2 (Cummins, 1981b). If parents refrain from using L1 at home and are not proficient themselves in L2, then they are more likely to expose their children to faulty application of the L2 which will inhibit the children's proper development of L2. On the other hand, if the parents are proficient in L2 but refrain from using L1 at home, then they simply deprive their children of the chance of becoming fully bilingual even though their children's development of L2 might not suffer per se. The bottom line is that when parents support the development of L1 at home through reading activities and regular interactions, they are raising their children's chances in succeeding academically in both L1 and L2 through further development of essential cognitive/academic language proficiency (Cummins, 1981a).

While some research has shown that bilingual students acquire higher levels of academic achievement (De Avila & Duncan, 1985; Lambert & Anisfeld, 1969), other studies have shown that continuous switching between home and school languages seems to result in inadequate command of both first and second languages (Cocking & Chipman, 1988). Mismatch between home and school languages demands that students acquire new set of linguistic constructs and rules in order for them to think and express themselves in the mathematics classroom (Adetula, 1990). Macnamara (1967) proposes that in order to achieve balance, a bilingual child sacrifices some of his L1 skills to attain skills in L2. Macnamara (1967) also claims that mismatch between home and school languages leads to "retardation in subject matter taught" especially when students are taught through the weaker language (cited in Cummins, 1979). However, experimental studies that show students studying in a second language matching or excelling over those studying in their mother tongue, refutes Macnamara's "balance effect" claim and suggests that other social factors might play a role in determining the level of academic achievement of bilinguals (Cummins, 1979). It is highly recommended to initiate schooling for bilinguals in their first language in situations where the home language is not highly valued by the community at large, where either teachers and/or pupils are insensitive or ignorant about their values and traditions, and where no support or pressure exist within the home to maintain literacy in their first language. Otherwise, where literacy is greatly valued and highly encouraged, it seems fully appropriate for bilinguals to begin schooling in the second language (Cummins, 1979). In order to better understand the interaction between initial instruction in their first language and academic progress, one needs to explore two main child input factors: conceptual-linguistic knowledge, and motivation to learn L2 while maintaining L1.

Quality of Acquisition of Second Language

Social Class and Background Factors

The social and cultural aspects of bilingualism play an important role in determining not only how fluent a person becomes in each language, but also the preference for use of one language versus another, or possibly both, in different situations and circumstances (Duran, 1985). Factors such as the prestige of L1, security of children's identity and self-concept, and level of support for L1 development and maintenance in home and environment affect the level of success of students in bilingual educational programs (Cummins, 1981b).

There are four possible outcomes to how minority language children identify themselves when participating in two different cultures: (1) they tend to closely identify themselves with both cultures and hence are more likely to achieve high levels of competence in both languages compared to (2) children who reject both cultures; (3) they might identify themselves with their own L1 culture and reject L2 culture and hence might resist learning L2; (4) they might identify themselves with L2 culture and reject their own L1 culture and hence might promote learning L2 which gradually replaces L1 (Cummins, 1979). Children who reject both cultures often end up unable to fully identify themselves with either of the two cultures (Cummins, 1981a).

Factors concerning acquisition of new languages, children acquire whatever language is spoken around them, even if their parents speak more than one language. As was the case with Von Glasersfeld, he was able to learn both German, his mother tongue, and English languages by the age of six. What is worth pointing out is that his parents used to speak in English whenever they didn't want him to understand what they were talking about. That in itself motivated him to learn English and he took it as a challenge that led him to succeed without special help or instruction. Interesting to note, is that applied linguists recognize that motivation, attitude, learning style, and character affect how skillfully a person learns another language (Von Glasersfeld, 1995).

Another factor affecting the level of difficulty of learning a second language is the age at which the student is exposed to the second language. Even though older second-language learners may possess higher developed skills that make it easier and quicker for them to learn the second-language than younger students, it is more challenging for them to produce more accurate and formal aspects of the language than younger learners. As second-language learners progress through school, the challenge to learning posed by the language becomes greater (Dawe, 1983). Moreover, the social and cognitive abilities of the students along with their desire and motivation determine the rate at which they learn a second language (Duran, 1985). Also, certain aspects of the student's own native language and culture play a critical role in facilitating or inhibiting learning a second language.

Different Levels of Bilinguality

When referring to the language skills of a student, different terms are used to distinguish between native speakers of that language and those who are not. The term verbal ability is used to refer to a continuum of verbal skills observable in native speakers, while the term language proficiency is used to refer to language skills of persons who do not exhibit native-like skills (Duran, 1985). For students to be considered bilinguals, they need to be proficient in both languages at least at the same level as that of an average monolingual student (De Avila, 1988). Students who possess less than native-like skills in both languages are described as "semilinguals"; in this case, their linguistic abilities have detrimental effects on their academic and cognitive progress (Cummins, 1979). Cummins (1979) also differentiated between "additive" bilingualism, where the bilingual child is adding or acquiring another language without diminishing his competence in L1; and "subtractive" bilingualism, where the bilingual child gradually replaces his L1 with a more prominent L2. "Additive" bilingualism has been associated with studies that found positive impact on the child's cognitive growth, whereas "subtractive" bilingualism has been associated with negative impact on the child's cognitive growth. In order for the child to benefit from acquiring a second language, the child needs to acquire high competence in L2 without diminishing competence in L1 (Cummins, 1979).

Cummins (1981a), through extensive review of research, builds a case for asserting that developing and maintaining L1 have a positive, rather than negative, effect on the development of L2 and on other academic skills. Promoting proficiency in both languages by using the minority language as means of instruction in immersion programs for majority language children as well as in bilingual programs for minority children has been proven effective (Cummins,1981a). Based on the review of several researches, Cummins (1981a) maintains that intellectual and academic advantages over monolinguals are experienced by bilingual students who develop and maintains their proficiency in both languages. This is supported by the language relativity theory known as Sapir-Whorf theory which suggests that a language is not simply a means of communication, but embedded in the language is a world view. In other words, individuals articulate their world view through their language. This suggests that people who acquire more than one language tend to have a broader understanding and perception of the world (Von Glasersfeld, 1995). However, acquiring a new language cannot be successfully achieved by merely learning a different vocabulary and a new set of grammatical rules. Consequently, learning a new language demands a higher level of complexity and sophistication when dealing with the world and daily issues (Von Glasersfeld, 1995).

Time spent on developing minority students' L1 proficiency can be accomplished in school without undermining proficiency in the majority language, L2 (Cummins, 1981). The Alberta government in Canada financially supports a program in eight Edmonton elementary schools since 1972 in which the medium of instruction for 50% of the regular school day is Ukrainian (Cummins, 1981). A study by Cummins and Mulcahy (1978) compared the performance of two groups of bilingual students attending the Ukrainian-English bilingual program in Edmonton, Canada against a monolingual control group from each of the first and third grade levels matched for IQ, SES, sex and age. The two groups of bilingual students differed in the amount of Ukrainian spoken at home which affected the degree of fluency of the student in Ukrainian. The study found that bilingual students who were relatively fluent in Ukrainian as a result of parents using it consistently in the home, performed significantly better on analyzing ambiguities in the sentence structure than the other groups with and without feedback cues (Cummins & Mulcahy, 1978). The findings of this study is consistent with earlier studies that have shown early childhood exposure to two languages promote better linguistic awareness, more analytic processing of language input, and greater sensitivity to linguistic cues and feedback (Cummins & Mulcahy, 1978). An evaluation of a bilingual program used by certain schools in Santa Fe in which Spanish was used between 30 and 50 percent of the school day throughout elementary school found that children enrolled in that program performed significantly better in both reading and mathematics than those enrolled in an English-only program. Those who were enrolled in that bilingual program since grade 2, performed in reading at a similar level as their English counterparts by grade 5 and surpassed them in grade 4 and maintained equal if not superior level through grade 6 (Cummins,1981). These findings might impact the way administrators in full-time Islamic schools allot time for the instruction of Arabic, especially in the elementary grade levels in order to enable Arab-American students to achieve higher fluency in both languages as they progress in school.

The Linguistic Distance Hypothesis

In acquiring a second language, the language learner faces challenges or even advantages as predetermined by the similarities and differences between the two language systems (Duran, 1985). The differences between semantics, functions and status of languages are referred to in sociolinguistic theory as the linguistic (language) distance. Some languages have a closer affinity to English than others (Halliday, 1975). European languages such as Spanish, Italian, or French are conceptually closer and enjoy a higher status in English societies than ethnic minority languages such as Arabic, Urdu or Creole (Dawe, 1983). Assuming all other variables equal, the smaller the conceptual distance the less effort it takes to learn English as a second language (Dawe, 1983). Dawe (1983) reports that some psycho neurological studies suggest that the spatial and verbal reasoning abilities of bilinguals learning in English as a second language may be hindered by their first language setup which follows right to left order in reading and writing. Examples of such languages are Arabic, Hebrew and Urdu. Other structural variables mentioned in Duran (1988) that may hinder or support a language learner in acquiring a second language are word order variability, object-verb order, subject-verb agreement or lack of, and availability of passives or not. Furthermore, this effect may be carried over into the learning of mathematics, in particular when bilinguals are solving word problems in a less familiar language.

Language Proficiency

Nature of Language Proficiency

Some studies of childhood bilingualism are theoretical in nature, focusing on the relationship between bilingualism and intellectual development and cognitive style, while others are more practical, designing different treatment approaches based on these theoretical studies and studying their effectiveness. Unfortunately, very few studies actually measured linguistic proficiency to determine the extent of bilingualism. Most of the studies either grouped subjects on the basis of ethnicity, assuming similar linguistic proficiency or relied on self/teacher reported evaluation which is extremely subjective and unreliable (De Avila & Duncan, 1985). Failing to control for levels of linguistic proficiency might have serious effect on interpreting results (De Avila & Duncan, 1985). Furthermore, English language proficiency needs to be distinguished from English language achievement. The latter refers to skills learned by the child in the classroom in a structured setting, whereas the former refers to language skills learned in both school and natural settings (De Avila & Duncan, 1985). When both languages were assessed to control for differences in linguistic proficiency, fully proficient bilingual students performed consistently at higher cognitive levels on both Witkin and Piaget type tasks. A three-year cross cultural study was done by De Avila and Duncan (1985) examining the effects of several variables, such as family background, cognitive style, standardized achievement test, oral language proficiency, intellectual development, and teacher perception on achievement within, rather than between, ethnolinguistic groups. Around nine hundred children from first, third and fifth grades were selected from nine different communities: urban Mexican-American, rural Mexican-American, Puerto Rican, Cuban-American, Chinese-American, Franco-American, Native American Navajo, Anglo-American, and Mexican. All except the last group resided in some part of the United States; the last group lived in a large metropolitan Mexican city. De Avila and Duncan (1985) found that there was a positive relationship between each of oral language proficiency and teacher perceptions and student achievement. In other words, children with high levels of English language proficiency and/or children with higher status in the sight of their teachers showed higher levels of achievement. In a substudy in which subjects were regrouped according to degrees of bilinguality of the students ranging from totally bilingual (English and Spanish) to monolingual (either English only or Spanish only) while allowing students who are partially proficient in one or both languages to be in the middle. The study showed that the proficient bilinguals had the highest total score on the measure of intellectual development based on six different Piagetian tasks, whereas the late language learners had the lowest. The overall performance of proficient bilinguals on cognitive tasks exceeded all other monolingual and bilingual children. As De Avila and Duncan (1985) put it: "the more proficient the children were in each of their languages the better they performed on the dependent measures." Similarly, educators, testing and assessment specialists, and cognitive psychologists have been interested in better understanding how proficiency in a language affects the ability of non-English background students to solve problems (Duran, 1985).

Integrative proficiency refers to coordinating multiple language skills to perform everyday pragmatic tasks with language. While scores on tests designed to measure integrative proficiency were found to highly correlate with performance on tests of general cognitive abilities of monolinguals, the same cannot be expected from bilinguals. Usually, bilinguals tend to exhibit stronger skills in one of the two languages, or put differently, non-native like proficiency in at least one of their languages. Hence, in order to understand the problem-solving performance of bilinguals, their language abilities need to be assessed at two different levels. First would be a general proficiency test entailing coordination of numerous modalities of language use in each of two language systems. Secondly, a test assessing the student's ability to solve word problems involving the use of particular language modalities and codes. Performance of bilinguals on problem solving tasks in each of their two language systems can be used to identify similarities and differences in information-processing behavior across the two language systems. This is what this study hopes to discover in the word problem processing of Arab-American students across the two language systems: the Arabic and the English. Moreover, adhering to De Avila and Duncan's call for controlling for differences in linguistic proficiency, SAT reading comprehension scores of Arab-American students were used as a covariate in my study to control for the students' comprehension levels in the English language. On the other hand, it was also important to control for the Arab-American students' levels in the Arabic language, and hence their final average in the Arabic school subject was used as another covariate.

Cummins (1981) distinguished between the language proficiency in basic interpersonal communicative skills manifested in everyday basic interpersonal communicative situations processing meaning through situational and paralinguistic cues and cognitive/academic language proficiency related to literacy skills manifested in decontextualized academic situations. The cognitive/academic language proficiency tasks are more relevant than basic interpersonal communicative skills tasks in promoting deeper levels of language proficiency for academic placement purposes (Cummins, 1981). Hence, using the minority language in instruction in the early grades not only promotes proficiency in the basic interpersonal communicative skills but also endorse cognitive and academic skills necessary to increase literacy in both the bilingual's languages (Cummins, 1981).

Cummins Theory

Cummins (1979) developed two hypotheses to support his claim that L1 needs to be adequately developed for bilingualism to be beneficial both academically and cognitively. The first, the "developmental interdependency" hypothesis, suggests that the level of competence already developed in L1 affects the development of competence in a L2 at the time when rigorous exposure to L2 begins. Cummins (1981) states the "interdependence" hypothesis as follows:

> To the extent that instruction in L_x is effective in promoting proficiency in L_x, transfer of this proficiency to L_y will occur, provided there is adequate exposure to L_y (either in school or environment) and adequate motivation to learn L_y. (p. 21)

Cummins (1979) asserts that intensive exposure to L2 in the early grades for children who have weak skills in L1 will probably hamper further L1 development. On the other hand, language minority students whose linguistic abilities in L1 are well developed to the abstract level before acquiring L2 seem to be more successful in acquiring L2, such as immigrant children who arrived from Mexico with a firm command of the Spanish language versus native-born Mexican-Americans (Cummins, 1979). Hence, the level of abstraction of the mother tongue seems to play an important role in facilitating L2 competence which in turn is essential in developing abstract knowledge in the subject matters (Cummins, 1979). Dawe (1983) found strong evidence to support the developmental interdependence hypothesis for Punjabi and Mirpuri bilinguals, but not for Italian bilinguals. Dawe (1983) found that high L1 competence and a specific knowledge of logical connectives were associated with high scores on the test of deductive reasoning, while low L1 competence and weak knowledge of logical connectives were associated with low scores on the test of deductive reasoning. Since Italian bilinguals where highly English literate and strong in both reading comprehension and the use of logical connectives, L1 literacy and intellectual development seemed to be the distinctive characteristics instead of English competence and knowledge of logical connectives. Furthermore, Italian family members, the fathers in particular, have shown greater efforts in becoming fluent in the English language than the family members of the Punjabi and the Mirpuri bilinguals. Also, as far as the status and linguistic grounds, Italian is much closer to English than any of the other languages involved in this particular study.

Cummin's second hypothesis, the "threshold" hypothesis, suggests that in order for a bilingual child to both prevent cognitive disadvantages and be positively influenced both cognitively and academically, the child needs to attain threshold levels of linguistic competence in both languages, i.e. L1 and L2. Cummins (1979) further suggested the existence of a lower threshold level and a higher threshold level, where it is sufficient for a bilingual to attain a lower threshold level of competence in both languages in order to avoid any negative cognitive impact; however, attainment of a higher threshold level is essential to accelerate academic and cognitive growth. Bilingual children can function adequately in early grades with relatively low level of cognitive competence in the language, however as the content becomes more abstract requiring higher and more formal thought processes and expression, bilinguals need to develop deeper levels of linguistic skills and comprehension (Cummins, 1979). Based on the review of several studies, Cummins (1979) found that for language minority students, maintaining L1 skills while acquiring L2 skills is a requirement for these students to attain higher threshold levels of bilingual competence. According to Cummins (1981), instruction by means of the minority language has been effective in promoting proficiency in both languages for majority language children enrolled in immersion programs and for minority children enrolled in bilingual programs. Hence, using L2 for majority language children and L1 for minority language children in educational programs promotes higher proficiency in both languages. Dawe (1983) found that Mirpuri bilinguals were able to reason deductively in English as a second language at a higher mean level than their English peers which greatly support the advantage of having an upper threshold level in bilingual competence. It is essential to point out that this L2 competence was attained at no expense to their L1 competence.

In his literature review, Dawe (1983) found several studies that supported the superiority of bilinguals in their divergent thinking abilities and flexibility of thought which puts the bilinguals at a slight cognitive advantage in learning mathematics over monolinguals. Okoh (1980) studied the relationship between bilingualism and creativity on a sample of bilingual and monolingual elementary students aged 9 to 11 residing in Nigeria and in Wales. All of the bilinguals from Nigeria spoke Yoruba and English and all of the bilinguals from Wales spoke Welsh and English; monolinguals from both countries spoke English only. Okoh (1980) found that when intelligence and language proficiency were controlled for the bilingual and monolingual groups, the bilingual group achieved significantly higher scores on verbal tests of creativity but not on nonverbal creativity tests. The findings from Okoh's study seem to suggest that the number of languages spoken, verbal intelligence and language proficiency are all critical factors influencing potential verbal creativity.

Mathematics and Language

Difficulties faced by language minority students were viewed by most educators to result from lower levels of intellectual development associated with bilingualism, differences in cognitive styles, deficiencies in motivation, and a multitude of factors grouped under socioeconomic status (De Avila, 1988). Language is crucial in the teaching and learning processes by which meanings are developed and shared within the classroom (Khisty, 1995). According to Cuevas (1984), a major source of underachievement in school is students' inability to understand the language of instruction. In fact, Aiken (1972) points out that mathematics itself is a "specialized language" and that students' performance in mathematics, particularly on verbal arithmetic problems, is greatly affected by their linguistic abilities. Adetula (1990) goes further to note that word problems denote "a language within a language". Based on review of several investigations, correlations between reading ability and mathematics achievement were found to range between .40 and .86 among students, the majority of which are in the intermediate grades (Aiken, 1972). Among the three factors: reading comprehension, problem solving abilities and computational ability, the partial correlation between reading comprehension and problem solving abilities was higher for both fourth and eighth graders than the partial correlation between computational ability and problem solving ability, with the third factor partialed out in both correlations(Aiken, 1972). In addition to having reading ability and mathematics achievement related to each other, they were also correlated with general intelligence (Aiken, 1972). Other studies reported by Aiken (1972) found that difficult vocabulary and syntax continue to be an impediment to successful problem solving. When students were given specific instruction in mathematics vocabulary, their problem-solving abilities improved (Aiken, 1972). In another study, high school students who were taught by a teacher stressing understanding of the meaning of mathematical terms and symbols did better on a criterion mathematics test than students who lacked that kind of instruction (Aiken, 1972).

The ability of a language user to reflect on and analyze spoken or written language is referred to by many researchers as *metalinguistic awareness* (MacGregor & Price, 1999). Metalinguistic awareness enables the speaker to pay attention to the form and function of the word or phrase, not just its meaning. Students need to operate at a level of abstraction similar to metalinguistic awareness in order to correctly manipulate algebraic expressions and analyze mathematical structures. MacGregor and Price (1999) identify *symbol awareness, syntax awareness* and *awareness of potential ambiguity* to be components analogous to those of metalinguistic awareness. With symbol awareness, symbols are detached from their real-life referents and used as basic meaning-units, such as (x+2). Syntax awareness refers to forming valid algebraic expressions (e.g. $2x=10 \rightarrow x=5$ is syntactically correct whereas $2x=10=5$ is not) and forming legitimate inferences (e.g. $a-b=x$ does not imply that $b-a=x$). Awareness of potential ambiguity refers to the ability to recognize potential multiple interpretations/misinterpretations of the same algebraic expression depending on the context (e.g. the use of brackets versus order of operations as well as the mistranslation of algebraic expressions such as "There are six times as many students as professors").

Verbal Problems and Translation Issues

In working verbal problem-solving tasks in a less familiar language, bilinguals employ a variety of strategies, such as mentally translating information from a less familiar language to a more familiar one or substituting the meaning of unfamiliar words for meanings of words in another language under the false impression of equivalency (Duran, 1985). Another most noticeable feature in producing written or spoken utterances is the presence of awkward or incorrect syntax and word usage which indicates an endeavor to transfer knowledge of language structure from one language system to another. In an attempt to solve a novel linguistic situation, a language learner may erroneously try to apply a learned grammatical rule that might apply in some but not all instances, such as appending the verb root with an "ed" to form the past tense of that verb. Similar generalization strategies may be utilized by language learners when trying to interpret problem-solving information in a less familiar language (Duran, 1985).

Many studies have also shown that students' difficulties and poor performance in mathematical problem solving are more of a linguistic nature rather than intellectual or cognitive (Dawe, 1983; De Avila & Duncan, 1985). Bernardo (2002) showed that bilingual students tend to perform better when problems are presented in a purely numeric format than with word problems presented in either their first or second languages. Obviously, the linguistic factor present in word problems makes reaching an answer less straightforward and more challenging than when the problem is completely presented in numeric format (De Corte & Verschaffel, 1987). This influence of language on problem solving skills is particularly significant for students who are bilingual and are considered to be language-minority students. Bilingual Hispanic ninth-grade students who were enrolled in Algebra I often solved word problems incorrectly even though they possessed similar mathematical and computational abilities as their monolingual peers. Their mistakes reflect their misinterpretation of the word problem due to their linguistic limitations, even though their solutions may be consistent with their own understanding of the problem statement (Mestre, 1988). Morales, Shute and Pellegrino (1985) found that the main contributor to errors in solutions of upper elementary Mexican-American students was the selection of inappropriate procedure rather than computational deficiencies. Moreover, insufficient prior experiences acquiring proper problematic strategies may further contribute to the difficulties faced by bilingual students in comprehending and solving word problems (Bernardo, 2005). When ruling out the linguistic difference between groups of students tested, Morales, Shute and Pellegrino (1985) contributed these errors to lack of conceptual knowledge and schemata for problem understanding rather than linguistic abilities.

According to Cocking and Chipman (1988), based on their review of available research, there is a big gap in the mathematics achievement between language minority and majority students, with no evidence in research to attribute this gap to inborn differences in these two groups' general intellectual abilities. However, Dawe (1983) emphasizes that this gap reflects the current performance of ethnic minority children within the current school system rather than their actual potential. Based on evaluation of early programs, Cummins (1981) claims that the poor academic performance of many bilingual students is due not to their bilingualism but to the school's attempt at eradicating it.

Political Debate

Debating whether language proficiency affects the learning and teaching of mathematics is rooted in a political as well as an educational campaign over the distribution of limited school funds (Tate & D'Ambrosio, 1997). Students with limited English proficiency were at a disadvantage and unable to have *equal access* as mandated by the Civil Rights decision of 1974 (Cocking & Mestre, 1988). There developed a debate among educators over who deserves to enroll in special language programs and what constitutes a deficit in language proficiency that is vital for academic success. The main concern is to address the needs of limited English speaking students to ensure "equal access" for all students (Cocking & Mestre, 1988).

While students with limited English proficiency are placed in special programs to support them, unfortunately, these programs give emphasis to rote memory skills sacrificing higher order intellectual processes. While these classes are designed to allow them access to better education and success, they contribute to intellectual deficiencies which inhibit their future success (De Avila, 1988).

Mathematical Communication

Current classroom practices in American classrooms focuses on teaching a body of factual knowledge as a prerequisite for students to think making it essential for minority students to acquire English language in order to 'think' successfully in class (De Avila, 1988). Since the reform movement of the mathematics instruction is calling on teachers to focus more on students' ability to explain solutions, provide evidence to support the validity of their number manipulations, and engage in constructive discussions with their peers, mathematical communication becomes an integral aspect of mathematics learning. To avoid viewing bilingual students as learners with deficits (Mestre, 1988), it is essential to study obstacles faced as well as resources used by bilingual students in understanding mathematical concepts. It is also important to view the variety of student languages as differences rather than deficiencies (Cocking and Chipman, 1988). Ferdinand de Saussure, known as the father of modern linguistics, laid down an important principle, namely that the meaning of words is to be found in the minds of speakers, rather than consider them as reflecting fixed meaning that can be shared by different speakers (Von Glasersfeld, 1995). This eliminates the traditional philosophical 'Theory of Reference' that claims words refer to things-in-themselves. Consequently, from a constructivist point of view, meaning cannot be shared by different members of the same community, but rather meanings can be compatible with each other. Each individual subject their constructed meanings to a never ending process of adaptation to establish mutual compatible associations that can produce comprehensible communication with different speakers. Therefore, the basis for communication is the assumption that whatever re-presentation the speaker has associated with a word is somehow similar to the re-presentations the word brings forth in other users of the language (Von Glasersfeld, 1995).

Problem Solving Studies

The perspectives and approaches of the studies on the low achievement of the language minority child have varied from blaming the child's own cultural and social characteristic to focusing on learning styles and cognitive abilities to studying attitudes and perceptions of teachers toward language-minority students (De Avila & Duncan, 1985). While previous models focused on pointing cognitive limitations and handicaps students with Limited English Proficiency came with, lately, concern is shifting to how well teachers are prepared to work with these students and provide the extra assistance in language processing while at the same time utilizing the students' resourcefulness in expressing themselves.

Moschkovich (2002) argues that using a situated-sociocultural perspective in describing the resources that students use to communicate mathematically, allows us to widen our view of competence in communicating mathematically and helps us move away from describing obstacles and deficiencies of bilingual learners. Within this perspective, participants bring multiple views of the situation in which representations have multiple meanings, and hence learning occurs naturally through conversations and negotiations within the social and cultural context of the participants.

As Moschkovich (2002) explains, students use more than words and utterances to communicate meaning. They may also communicate through the use of artifacts, gestures and other nonverbal behaviors in order to get the message across in a mathematical conversation. For example, in a class where both students and teacher were bilingual (spoke both English and Spanish), a student trying to explain how changing the dimensions of the rectangle affects its perimeter was unable to name the geometric shape (in this case, the rectangle) nor was she able to use proper language using the word 'higher' instead of 'greater'. However, she was able to compensate for her lack of mathematical vocabulary by tracing the shape of a long rectangle with her hands several times and using correct mathematical comparison conveyed by her statement: "the longer the ________(meaning the shape of the rectangle), the more (higher) the perimeter." Focusing on the missing or inaccurate vocabulary would unjustly focus on the student's incompetence in communicating mathematically correct statements. However, the student was able to use other resources to compensate for the linguistic shortcomings. Teachers need to recognize the different means through which bilingual students express mathematical ideas in order to provide equal opportunities for all students to participate in classroom discourse (Moschkovich, 2002).

Better recollection of word problems given in L1

In another study by Bernardo (2002), Filipino-English bilingual students showed more accurate recollection of word problems read to them in their first language than in their second language. In fact, students whose first language is Filipino made more structure preserving alterations when recalling problems given in their first language and made more structure violating alterations when recalling word problems given in their second language. This first language advantage was reflected in students' ability to understand and solve problems in their first language whether it was English or Filipino; however, this advantage was more marked in easy problems than in difficult ones. A study by Lambert (1955) cited in Duran (1985) found that bilinguals' reaction times to simple oral instructions were longer when given in a less familiar language than a more familiar one. Research has already established that bilinguals usually take longer time reading sentence-long materials in a less familiar versus more familiar language (Duran 1985; Macnamara, 1967). In another study cited in Duran (1985), reaction time to oral instruction in the less familiar language was inversely related to self assessments of proficiency level in that particular language. In other experiments by Bernardo (1996, 1998), Filipino-

English bilingual problem solvers were better at transferring knowledge to analogous problem situations when the language used in the source and target problems was the same regardless of whether this language was their primary or secondary. Bernardo (1998) also noticed that American- or British-trained Filipino scholars tended to have difficulty expressing knowledge acquired in another language. This language specificity in processing information in certain domains highlights the effect of language on accessing analogous problem information and adapting it to new problem situations. The significance of this to bilingual students is that their ability to understand and process certain concepts and procedures maybe lacking due to difficulty accessing knowledge acquired in a different language.

Language system effect on bilinguals' problem solving ability

Researchers have been conducting research trying to find out whether the language system used to teach and learn concepts and skills has any effect on how bilinguals acquire knowledge, especially in highly abstract and symbolic domains such as mathematics (Duran, 1988). Bernardo has expressed special interest in the relationship of language and word problems since word problems constitute an important component of the mathematics curriculum, and is heavily relied upon in measuring mathematics achievement across countries in tests like TIMSS, Third International Mathematics and Science Study. An essential prerequisite to ensuring students' success in solving word problems is their ability to comprehend the problem. The source of difficulty of solving mathematics word problems is sometimes comprehending the problem rather than manipulating the numbers (Knight & Hargis, 1977). Through error analysis of the students' solutions in a study done by Bernardo (1999), results indicated that better comprehension of the problem text contributed to higher performance in solving problems. While limited ability in English may not be the sole factor affecting the educational attainment of students from non-English speaking backgrounds, it is nevertheless a major contributor to problems faced in academic functioning (Duran, 1985).

Reading comprehension and problem solving

According to Duran (1985), formal problem-solving situations that are encountered in academic settings may be divided into three interactive sets of activities: (1) *problem input* where a problem solver acquires and interprets information about a problem situation; (2) *problem representation and conceptual solution* where a problem solver undergoes purely mental acts to solve the problem; and (3) *physical execution of solution steps* where the problem solver physically executes steps to solve the problem and communicates solution in a comprehensible manner. The problem solver may not necessarily follow these three sets of activities in sequence.

Several studies found a strong correlation between the level of student's linguistic abilities and mathematics achievement (Dawe, 1983). In fact, several studies found that the relationship between language and mathematics achievement is so strong that mathematics performance is greatly dependent upon a special kind of language proficiency (Cocking & Chipman, 1988; Earp & Tanner, 1980) refuting older belief that mathematics was a subject that did not depend much on language (Dawe, 1983; Kessler et al., 1986; Spanos et al., 1988). This popular belief of mathematics being relatively "language free" lead teachers to expect higher success rate with little difficulty in doing mathematics for bilinguals, provided it being done in their first language (Kessler, Quinn, & Hayes; 1986). Morris (1975) recommends that when teachers teach mathematics in a second language, they need to adopt methods of teaching a second language as a language in order to be successful. Second-language learning is made more difficult when the student first learn the language of the textbooks which is different from their first language (Cuevas, 1984). Furthermore, the reading level of the mathematics textbooks and materials needs to match the reading level of the student; if not, either lowering the reading level of the textbooks or improving the reading levels of the students is essential in order to be successful in teaching mathematics (Earp & Tanner, 1980).

MacGregor and Price (1999) studied the effect of language proficiency on algebraic learning of students in Grade 8 through 10 in a middle-class suburb of Melbourne and found that, contrary to the popular belief, low ability in language is a barrier to high achievement in mathematics, in particular, learning algebraic notation. Results from the first study showed many students with high scores on language items had low scores on algebra items, however, none had low language score and high algebra score. The reason for predominantly high scores on the language items is partly because language items students were tested on were easier than the algebra items, which was indicated by the distribution of scores. The language scores were extremely skewed to the right, whereas the algebra scores were more evenly distributed. This defect was corrected in a later study by the same authors whereby no student with very high language scores had very low algebra scores. Only English-speaking-born students were considered in the second study in order to minimize the confounding effect of a variety of linguistic and cultural variables. Data from students whose first language was not English was excluded from analysis of results for two reasons. First, low scores might reflect difficulty in understanding the questions if their English was not well developed. Second, on the other end, high scores might reflect a "cognitive advantage" that well established bilingual students may have over their monolingual peers due to better metalinguistic awareness. Results from both studies showed some students with good language scores made mistakes in many algebra items. The authors justify this shortcoming on the possibility of students' unawareness of algebra having a separate set of grammatical rules and conventions or that they had poor mastery of the algebra taught in the introductory courses. Students who take introductory courses of algebra fail it due to their poorly developed metalinguistic awareness rather than lack of "general intelligence" or "cognitive ability". The researchers suggest that for these students, their learning of algebraic notation might be accelerated if they develop their metalinguistic awareness first until they reach an adequate level of mastery. MacGregor and Price (1999) suggest that poorly developed metalinguistic awareness limit the students' ability to understand the algebraic notation. This study supports Adetula (1990) claim that the student's ability to apply mathematical knowledge and skills when solving word problems was greatly impacted, even restrained by the ability of effectively processing the linguistic component present in the word problems. This finding is particularly significant for bilingual students who have to solve word problems written in their weaker language. In other words, difficulties in understanding word problems lead to errors in the solution of these problems as shown by research done by Cummins, Kintsch, Reusser, and Weimer (1988) and by Riley and Greeno (1988).

Other studies by Bernardo (2005) provide further support to the idea that Filipino-English bilingual students tend to better understand word problems in their more proficient language, usually their mother tongue, regardless of the language of mathematics instruction. Adetula (1990) focused on Nigerian students enrolled in primary grade 4 from both private and public schools. In Nigeria, well-equipped private primary schools teach all subjects in English in addition to the mother-tongue as a separate subject starting from primary 1; whereas, public schools teach all subjects in the mother tongue for the first three years of school, then use English and the mother tongue starting from the fourth year of schooling. Adetula asked a total of 48 children from primary 4, half of which were in private schools and the other half in public schools, to solve a total of 20 arithmetic word problems involving "more" or "less" as distracter and valid cues, half were presented in English and the other half in their mother language. Adetula found that all students performed better when problems were presented in their native language rather than in English, however results were only significant ($P<.025$) for public school students. It is essential to point out that the English language, not the mother tongue, is the language that is highly regarded by society as the tool of advancement in education and in professional careers.

Context sensitivity/language specificity

A powerful skill that helps students comprehend mathematical words is the ability to use contextual clues and get more practice in paraphrasing mathematical statements (Earp & Tanner, 1980). In fact, interpreting words were affected by whether the function of the problem was for mathematics use or merely for telling a story. In a study done by Bernardo (1996), bilingual students were presented with word problems that utilized the words “more” and “less” and were framed as either mathematics problem or stories. The subjects were Filipino-English with Filipino as their first language. Subjects were more flexible in accepting inexact meaning of the words as true when the text was framed as a story rather than a mathematical problem. Moreover, subjects were more likely to consider alternative meanings of the words in the story frame employing longer processing time as opposed to the lack of ambiguity demanded by the problem frame. This context sensitivity exhibited by the students had significant repercussions on the underlying assumption that students will be able to transfer their acquired skills to other situations.

Another finding of Bernardo (2005) is that students rarely considered real-life constraints when solving word problems. This failure, which is supported by prior research, does not seem to be dependent on linguistic factors. Yoshida, Verschaffel, and De Corte (1997) found that Japanese and Belgian children tend to ignore any realistic considerations when solving word problems despite attempts from researchers to scaffold children by giving them extra hints such as make a drawing or visualization of the problem situation. According to Yoshida, Verschaffel, and De Corte (1997), ignoring real-life constraints might not be attributed to limited linguistic abilities, but rather to restrictive classroom practices that make students get used to solving standard predictable word problems with well rounded numbers. Teachers tend to emphasize computational proficiency rather than focus on students' modeling abilities and interpreting skills. Merely asking students to think critically and to visualize a problem was not enough for helping students move beyond their customary approach to solving problems. Such a change demands a fundamental shift in classroom practices to prepare students to become critical thinkers and seize to expect standard problems that do not challenge student thinking.

In my pilot study at a local school, bilingual students mistakenly understood the word 'opposite', as used in everyday language, to signify 'contrary meaning' (e.g. tall is opposite of short) instead of the mathematical use of the word to signify 'contrary position' (e.g. side AB is opposite to side DE). On another occasion, one of the questions in a written test asked the students to find the difference between 3.8 and 8, four students out of eight (50% of the students) gave a written description of how these two numbers differed instead of performing subtraction and finding the answer intended by the question. Khisty (1995) also refers to the confusion between the meanings of the word *left* when used in the natural discourse to signify direction versus the mathematical meaning as in: 'how many are left?' English speaking students have the advantage over Limited English speaking students for their ability to identify these subtleties with the meanings of same words in different contexts.

Investigations by Aiken (1972) that required participants to think aloud and verbalize their tactics while solving problems, revealed that when encoding the problem, subjects who were physically inclined seem to translate algebraic equations into some kind of internal representations, while subjects who were verbally inclined seemed to literally translate the words of the problem. Furthermore, individuals varied in their problem-solving abilities and techniques. Children usually use key words in a problem to help them select an operation. For example, "more" typically indicates using addition and "less" indicates using subtraction. That may not be the case always. An example of such occurrence is: "The milkman brought on Monday 7 bottles of milk. That was 4 bottles *less* than he brought on Sunday. How many bottles did he bring on Sunday?" (Adetula, 1990). Word problems that utilize terms like "more" or "less", "take away" or "left" as distracters rather than valid cues are generally more difficult, but useful in examining the level of comprehension of the student to surpass the superficial meaning of the word which might lead to selecting an incorrect mathematical operation.

Operations expressed in a multitude of ways

Spanos and his colleagues (1988) noted that single mathematical operations that can be described using synonymous words and phrases, can be problematic to students who are not keen on the English language. Students who can only express a mathematical concept in one way can easily get lost when the same concept is referred to by others (whether teacher or students) using different terminology, as was the case when 'three-quarters' and 'three-fourths' were used interchangeably during an upper-grade class discussion where a sizable number of students are either non-English proficient (NEP) or limited-English proficient (LEP) of Mexican descent (Khisty, 1995). Teachers can help students overcome the linguistic ambiguities of mathematics by "recasting" mathematical ideas and terms through discussing other ways of looking at the problems as well as providing students with some of the synonyms relevant to that particular problem.

Translating algebraic expressions

Translational errors reflect student difficulties with word-order matching and mapping words with mathematics symbols rather than simple carelessness. Students who perform poorly in mathematics also show low verbal abilities which might explain their poor mathematics performance. Researchers have recently explained that students first translate the English statements in a word problem into mathematical representations before proceeding with the solution which make it three fold difficult for bilingual students who deal with another level of language translation (Cocking and Chipman, 1988). Trying to better understand the translation issue, Clement, Lochhead, and Monk (1981) found that students had difficulties conceptualizing within the language of mathematics.

Another area of difficulty is represented by problems that ask students to distinguish between variables and labels. An example is the student-professor problem: 'There are 6 times as many students as professors at this university. Write an equation to express this relation.' 54% of a population of Hispanic engineering students made the mistake of reversing variables by writing 6S=P instead of S=6P. Explaining how to translate algebraic expression and then verbally expressing their way of thinking are challenging to limited speakers of English.

A study was conducted by Mestre (1988) on 6 English/Spanish bilingual Hispanics, 5 English speaking monolingual students and 3 Hispanic students enrolled in advanced Algebra class (the word 'advanced' refers to the level of Algebra class not the language proficiency of the students). Through interviews with the students, Mestre studied the students' ability to translate algebraic word problems into equations. Students often face difficulties "making the transition from the lack of precision inherent in natural discourse to the precision necessary in mathematical discourse." Identifying difficulties caused by translating from textual to symbolic representation highlighted the semantic factors inherent in the language of mathematics. Statements like 'a number added to 7 equals 18' and 'nine times a number results in 36' are considered straightforward posing little challenge to the students. In contrast, the statement 'in 7 years, John will be 18 years old' was less straightforward requiring students to use deduction to figure out that John's current age was the unknown. Mestre (1988) found that students were more prone to commit an error when the variable was less discernible in the algebraic statement than when it is clearly stated in the beginning of the statement. Other researchers (De Corte, & Verschaffel, 1987) found that students' accuracy level in problem-solving is significantly improved when the text of the word problems was reworded in a manner that better reflected the problem structure. In other mistakes, some students translating the statement 'Six times a number is equal to a second number' mistakenly included a '2' in their algebraic expression (e.g. 6X=2 or 6N=2N) literally reflecting the semantics of the problem.

Use of Primary Language in Instruction

The use of the student's primary language in instruction provides the student with much needed support and is reflected in the academic gains (Cummins, 1981). Furthermore, the use of the student's primary language is essential in clarifying any possible confusion that might occur in understanding mathematical terms and their use in different contexts. Llabre and Cuevas (1983) found that Hispanic students who are instructed in their native language appear to have high achievement in the school subject. Researchers need to determine the level of bilingualism of the teacher and how second language is being used in instruction. Khisty (1995) found that, in a classroom where even though most of the students did not speak English well, teachers only used the Spanish language for disciplining students or giving words of encouragement or motivation to the students on an individual basis. However, Spanish was not used as a tool for explaining mathematical concepts and developing shared meaning. Khisty (1995) found that even though teachers spoke Spanish, they were unable to explain concepts using Spanish vocabulary because they lacked training in the technical aspects of the language. When students struggle to understand teacher's instruction because they are unfamiliar with the language of instruction, students will start feeling alienated from mathematics and unable to achieve mastery in the subject.

Tests and Language

Some researchers (Tsang, 1984; Llabre & Cuevas, 1983) argued the inappropriateness of tests given to language minority students in a language not understood by these students. Bilingual learners are more prone to make mistakes when the language of performance and assessment is not their dominant language (Mestre, 1986; Macnamara, 1967; Morales et al., 1985, Bernardo, 2002). A study cited by Cocking and Chipman (1988) found that bilingual students scored higher in Mathematics Placement Test when they performed the test in the language they were instructed in or in their dominant language if they are not fully bilingual. Recommendations given by Llabre and Cuevas (1983) include taking into consideration the primary language of instruction, the student's level of reading proficiency in that language, and the skill being measured when interpreting the mathematics achievement test scores of a bilingual student. In order to truly assess the level of performance of bilingual students, test items need to be formulated using vocabulary that is familiar to the students (Knight & Hargis, 1977).

Conclusion

The literature reviewed in this Chapter show that there is no simple remedy that can apply to all linguistic groups to improve their mathematics achievement. Indeed, because various ethnic groups rarely face similar problems with language or have any consistent ethnic patterns on test performance, it is hardly expected that the same remedy would benefit all groups (De Avila, 1988; Tsang, 1984; Cuevas, 1984; Charbonneau & John-Steiner, 1988). Hence, cultural teaching/learning practices that work with one ethnic group may not work as well with other ethnic groups or with other group of children within the same ethnic group. The current study aims to conduct further research in the area of mathematics problem solving as it relates to Arab-American students' comprehension levels in the home language and the language of instruction.

CHAPTER THREE

METHODOLOGY AND PROCEDURES

Introduction

Language is crucial in the teaching and learning processes by which meanings are developed and shared within the classroom (Khisty, 1995). Several studies found that the relationship between language and mathematics achievement is so strong that mathematics performance is greatly dependent upon a special kind of language proficiency (Cocking & Chipman, 1988; Earp & Tanner, 1980), refuting an older belief that mathematics was a subject that did not depend much on language (Dawe, 1983; Kessler et al., 1986; Spanos et al., 1988). According to Cuevas (1984), a major source of underachievement in school is students' inability to understand the language of instruction. This study focused on bilingual students who speak both English and Arabic and how their knowledge of those languages played a role in their ability to successfully solve mathematical word problems. This study also explored the relationship between the language of the word problem and the level of accuracy of the students' solutions to the word problems.

Purpose of the Study

While many students, including Arab-Americans, struggle in studying mathematics, there is a lack of research on exploring factors that might affect Arab-American students' performance in mathematics, particularly in solving word problems. My literature review showed that many studies found that limited proficiency in the language of mathematical instruction contributed to difficulties faced by bilinguals, especially when the language of instruction in the mathematics was in their weaker language. The National Assessment for Educational Progress (NAEP) reported that, in 2003, more than half of Limited-English-proficient (LEP) students in 4th Grade and almost three-fourths of LEP students in 8th Grade, performed below the Basic level nationwide; while only a small fraction of LEP students (less than one tenth) in 4th Grade and half as many in 8th Grade, performed at or above the Proficient level.

Arab students raised in the United States usually struggle with learning the formal Arabic language, even though it is their mother/home language. Both the Arab American students of this study and the Filipino students in Bernardo's study (2002, 2005) learned mathematics only in English and without any support or usage of their native language. For the Filipino students who learned mathematics in English, Bernardo (2002, 2005) found that they performed better in the Filipino version of the word problems. The difference though between his Filipino students and the Arab American students of this study, is that the Filipino students lived in their native country where they speak and practice their home language most of the time. Arab American students, on the other hand, speak English for the major part of their day with the exception of speaking Arabic when they are at home or when interacting with some members of their community. Bernardo (2002, 2005) found that Filipino students raised in a Filipino speaking society, but who have always learned mathematics in English, tended to do better when problems were presented in their native language (Filipino) rather than the language of instruction (English). My study investigates the likelihood of the Arab American students performing similar to the Filipino students in Bernardo's studies. The lack of research on this particular student population makes this study exploratory in nature and a first step that sets direction for future studies.

Research Questions

This study aims at exploring the relationship between the language of the word problems and the performance of the bilingual Arab students who are literate in both English and Arabic while controlling for their level of comprehension in both the English and Arabic languages as well as their level of performance in mathematics problem solving. With this focus, the study aims to answer three main research questions:

1. Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students? Specifically, is there a difference in the performance of Arab-American students when solving word problems in English compared to solving word problems in Arabic? Null Hypothesis: There will be no significant difference in the performance of Arab-American students when solving word problems in English compared to solving word problems in Arabic.

2. Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems? Null Hypothesis: Arab-American students with higher levels of Arabic proficiency will not perform better on the Arabic version of the word problems than on the English version.
3. What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic?

Procedures for Conducting the Study

Students were selected from a full-time Islamic school located in the Eastern region of the United States. An Islamic school is an ideal place to find a high concentration of Arabic speaking students with advanced level of Arabic proficiency who fit the criteria of subject selection for this study. The principals', teachers' and parents' permission were requested in order for the selected students to participate in this study. Students who did not wish to participate in this study were given word problems assigned by the teacher. The duration of the data gathering and subject's participation was 4 to 6 weeks.

Plan for school recruitment

A short principal survey (Appendix A) was distributed together with a letter of introduction to collect general information about the number of the student population in each grade level and the level of Arabic courses offered to students in grades 5 through 7. The principal survey was used to determine whether the school had enough students in the levels of Arabic and English proficiencies required in this study. In addition, the principal survey was also used to evaluate the student population and determine the standardized exams, if any, that were used to evaluate student performance in Arabic, English and mathematics at the school.

Plan for obtaining informed consent from parents

Once the school was selected and support had been confirmed, arrangements were made to set a time for the study. The teachers were asked to read and sign the letter of support (Appendix B) to administer this study in their classroom and to distribute to the parents the consent forms (Appendix C1,C2, & D) to all the students in grades 5, 6, and 7. The parents and students then read, signed and returned the consent forms the next day which were collected by the teacher and kept on school premises at the request of the administration. It was important for students to know that not participating in the study meant they would still do related classwork, for otherwise, they might have been tempted to not participate in the study. The researcher also made sure parents and students were aware that the results of this study would not be linked to the students' records.

Administering the Tests

Once the support and approval of the principal were obtained, the teachers were sent the letter of support for them to read, sign and send back. The word problem sets (Appendix E1, E2, F1, & F2) were administered to the students in their own classroom and by their own mathematics teacher. All parents supplied their approval for their children's participation in the study. However, a total of 29 students refused to participate in the study. The researcher personally assessed the student solutions.

Sample

Population

The researcher sought the participation of all of the 202 students from grades 5, 6 and 7 enrolled in that particular Islamic school in the Eastern region of the United States. This Islamic school consisted of two branches: one for girls and one for boys. The administrators of the school offered the researcher their full support through a formal written letter. The administration expressed support for all research efforts that might shed light on improving teaching practices for the Arabic bilingual students.

The girls' branch consisted of 44 fifth graders, 38 sixth graders, and 40 seventh graders. The boys' branch consisted of 29 fifth graders, 26 sixth graders, and 25 seventh graders. Due to the refusal of some of the students to participate in the study, the number of students actually participating were 27 fifth graders, 30 sixth graders, and 38 seventh graders from the girls branch; and 29 fifth graders, 26 sixth graders, and 23 seventh graders from the boys branch. Hence, the total number of participants was 173 students.

Sampling Method

Students from grades 5, 6, and 7 were selected for this study and were randomly assigned to four equal groups through a random number generator. Most of the students enrolled were literate in both languages: English and Arabic. Each group solved two sets of 10 mathematical word problems given on two separate school days. To control for reliability of test items and examine learner effect, groups 1 (Eng1/Eng2) and 4 (Ar1/Ar2) were formed.

Table 1 Description of groups with respect to language of each set

Group	Set 1	Set 2	Language of Sets
1	English	English	Eng1/Eng2
2	English	Arabic	Eng1/Ar2
3	Arabic	English	Ar1/Eng2
4	Arabic	Arabic	Ar1/Ar2

Each group was described by the language in which the word problems were written. For example, Group 2 being Eng1/Ar2 means that students in this group solved the word problems of set 1 in

English and solved the word problems of set 2 in Arabic. The following is a description of the language of each set and the order they were given to each group.

Selection Criteria

Selection criteria was based on schools having large number of students who are literate in both the Arabic and English languages. The school chosen for this study offered an American coordinated curriculum together with a strong Arabic and Islamic curriculum offered in the Arabic language. Students enrolled in this school had a strong foundation in the Arabic language as their first language.

In general, students enrolled in this particular school needed a minimum level of literacy in both languages in order to be productive. Part of the reason why this school had been selected was that both of the Islamic studies and social studies were offered in the Arabic language which required an advanced level of proficiency in the Arabic language. All other courses were offered in English. All of the parents of the students provided their permission to allow their children to participate in the study except one. Students who did not wish to participate in the study were required to solve word problems given by their teacher. As a courtesy to the mathematics teachers involved in the study, the researcher prepared an alternate set of word problem for both set 1 and set 2 that could be given to students who were not able or unwilling to participate in the study.

Instrumentation

The data for this study was collected via the following instruments:

A. Principal survey

B. Stanford Achievement Test (SAT10) for Reading, and for Mathematics Problem Solving.

C. Arabic final average given at the end of the academic year.

D. Two sets of word problems consisting of 10 problems each constructed by the researcher.

A description of each instrument and what each measures follows.

A. Principal Survey

The purpose of the principal survey was to collect general information about the student population enrolled in the school, particularly in regards to the number of students enrolled in grades 5, 6, and 7, the levels of Arabic classes offered at each of these grade levels, and the number of students enrolled in each level of Arabic per grade level. This information was vital to determining whether a school provided a sizeable student population with the required Arabic foundation appropriate for the purposes of this study. A good indicator of the level of students' Arabic proficiency was whether the school offered students any courses in Arabic. In particular, the researcher was interested in determining whether the Islamic Studies and/or Social Studies were offered in Arabic, since most regular full-time Islamic schools offer these two subjects in English. Other information provided by the principal survey were the types of standardized testing students take, which were later used as the covariates in the data analysis. The principal was asked to indicate whether the Arabic classes were partitioned to accommodate for students with varying levels of Arabic literacy. Finally, the principal was asked to give the number of students enrolled in the different levels of Arabic literacy in each grade level to assure an adequate number of students were enrolled at an advanced level of Arabic literacy in each grade level.

B. *Stanford Achievement Test*

The Stanford Achievement Test (SAT) is a standardized test that measures student achievement in reading, language, spelling, study skills, listening, mathematics, science and social science for all grade levels. Most test items are multiple-choice; however, there are some open-ended items and writing prompts available. To provide a more holistic means of evaluating students' skills, they are recommended to be used in combination rather than as alternatives. Having the reading selections of the SAT 10 written by children's authors is a unique feature of this battery. New test items were devised by test professionals and content experts to target higher order problem-solving processes. Test items within subtests are not arranged in the typical "easy to hard" order, but rather mixes easy and difficult items. This arrangement was found to keep students motivated to finish the entire set of problems instead of giving up when faced with a difficult problem thinking that all problems that follow will be more difficult. Even though calculators are allowed but not required to be used in the Mathematics Problem Solving subtest only, there was no statistical difference between the performance of students either using or not using a calculator for that subtest (Carney, 2005). Item tryouts were analyzed using the Mantel-Haenszel bias analyses and screening of the final test items was performed by a 20-member “Bias Review Advisory Panel” to minimize bias or stereotyping in areas pertaining to gender, ethnic, cultural, disability, or SES.

Changes in the school curricula and national assessment trends prompted the development of the tenth edition of the SAT in 2002. The standardization process involved 250,000 students in the spring and 110,000 students in the fall. The standardization sample was a close reflection of the 2000 U.S. population partition with respect to geographic region, socioeconomic status, urbanicity, and ethnicity. In addition to individual raw scores, several types of normative scores are offered by the Stanford 10 such as: individual percentile ranks, scaled scores, stanines, Normal Curve Equivalents (NCEs), group percentile ranks and stanines, and grade equivalents. Performance levels were also classified qualitatively to one of four levels: (1) Below basic, (2) Basic, (3) Proficient, and (4) Advanced.

The technical report stated that the Stanford 10 demonstrates a “high degree” of internal consistency reliability (Carney, 2005). Reliability of the SAT refers to the degree of consistency and dependability of the testing procedure and scores when performed repeatedly on a certain population (Berk, 1998). The majority of the Kuder-Richardson Formula 20 (KR20) coefficients calculated for the full-length test (Forms A and B) are in the mid .80s to .90s, which are considered satisfactory for the purposes of such a test (Carney, 2005). Alternate-form reliability measures the equivalency of Forms A and B, and shows that correlations across the various tests of both Forms ranging from .53 to .93, but usually in .80s. The composite scores of the "Total Reading" and "Total Mathematics" were usually close to .90.

The validity of the SAT is left to the user to determine whether the test items appropriately correlates with the school curricula and educational goals (Berk, 1998; Carney, 2005). Validity refers to the degree of compatibility of what the test measures with the actual curricula and goals set and taught at the particular school. Content validity is evident in the careful process of development of test items based on well-defined test blueprint revised as needed by test professionals and content experts. Test items were also subjected to extensive scrutiny by a qualified panel to free them from any bias or stereotype. Evidence of convergent validity is marked in the correlations between the various subtests and totals of the Stanford 10 levels with the subtests of the Stanford 9, which run in the .70s-.80s. Construct validity is evident in the correlations between the Stanford 10 and Otis-Lennon School Ability Test (OLSAT 8) (Berk, 1998; Carney, 2005).

C. Arabic Final Average

All of the students enrolled in grade 5, both boys and girls, were initially given a comprehension test in Arabic, and all of the students enrolled in grade 6 and 7, both girls and boys, were given another comprehension test in Arabic that was compatible with 5th grade test but covering a slightly more difficult content. Both tests were multiple choice. The tests included questions asking for synonyms of certain words, reading a short story and answering questions about it, choosing sentences that are written without any grammatical or syntactical errors. All the tests were corrected by the headmaster of the Arabic department. After reviewing the results, the researcher found vast discripancy in the Arabic test scores per grade level. The scores ranged from 13% to 100% in grade 5, 17% to 100% in grade 6, and 6% to 89% in grade 7. This enormous variation indicated either the students did not take the test seriously or the correction was not standardized across the grade levels. There are two major problems with this test. It was not comprehensive, nor was it standardized. Consequently, the researcher felt that this single test was not a true or fair measure of the student's comprehension level in the Arabic language. Alternately, the researcher decided, with the approval of the head committee member, to use the overall average in the Arabic subject given by the school at the end of the academic year. This grade acted as a general measure of Arabic competency.

D. Two Sets of Word Problems

The students were given two parallel sets of 10 problems each (Appendix E1, E2, F1, & F2). Each set contained five types of two analogous problems focusing on the following concepts: logical reasoning, thinking backwards, comparing the value of two options, the concept of “twice as”, and finally, the concept of “fewer than”.

Because the Arabic word problems were given to students in the written standard Arabic form which is unified throughout the Arabic region in the Middle East, variations in dialects found only in the spoken form of the Arabic language did not pose any problem for the present study. To make the reading of the problems less confusing and more transparent, additional marks were written over or below the letters in the Arabic version. These marks are not part of the Arabic alphabet, however their function is similar to the short vowels in the English language. As a quick overview:

- a ‘fatha’ is a little dash written over a consonant to indicate the short vowel “A”;
- a ‘kasra’ is a little dash written below a consonant to indicate the short vowel “I” or “E”;
- a ‘damma’ is a symbol that resembles a comma written over a consonant to indicate the short vowel “O” or “U”;
- finally, a ‘sukoun’ is a small circle similar to a degree notation written over a consonant to indicate the lack of a vowel.

Expert Arabic readers can read the Arabic text without the help of these marks, however the presence of these marks helped to eliminate any possible confusion, especially for the beginner/moderate readers.

The word problems for set 1 were mostly selected from a standard mathematics textbook used in the United States in an accredited fulltime Islamic/American school. The word problems for set 2 were mostly selected from an overseas mathematics textbook for fifth grade written in Arabic. The curriculum of the Arabic textbook covered similar topics to the curriculum taught in the American schools for this grade level. Set 1 was translated to Arabic and set 2 was translated to English; the result was four sets of 10 problems each where each two sets were identical in content but in different languages. The names of individuals/people mentioned in the word problems were matched to the language of the word problem. For example, problem 1 in set 1 talked about the Brown family in the English version, whereas in the Arabic version, it was the Yassin family which was a familiar name in the Arabic culture. The Arabic numeral digits (0, 1, 2, .., 9) were used in both the English and Arabic versions to minimize any unnecessary confusion for the students, since most students learn mathematics using these numerals. Due to the expected diversity of students participating in this study and the lack of cetainty that all students would be familiar with one specific middle eastern currency, all currency was expressed in the dollar value so as to be familiar for all, if not most, students participating in this study. Moreover, the topics of the word problems were scrutinized and selected to match the cultural standards and interests of the student population. For example, problem 8 in set 1 was initially about five students, girls and boys, participating in a swimming relay race. Such an activity might be either unfamiliar to some students, or unacceptable from an Islamic standard for boys and girls to be swimming together in the same race. Hence, the topic of the problem was changed to a running race where all participants were girls. Problem 5 in set 1 was modified from baseball practice to basketball practice, since participants are more likely to be familiar with basketball than baseball.

Translation of the word problems from English to Arabic for set 1 and from Arabic to English for set 2 was subjected to scrutiny by two fully bilingual university professors on several occasions mainly: once during the course of preparation of the word problems, and once at the end when all modifications were finalized for the word problems. Based on the feedback from both professors, several syntactical and grammatical mistakes were corrected and some questions were revised to remove any unnecessary confusions caused by the wording of the questions. For example, problem 6 in set 1 dealing with Mrs. Price selecting an appropriate plan for making long distance phone calls, the question at the end of the word problem was modified from: “Which plan should Mrs. Price use? Why?” to: “Which plan is cheaper? By how much?” Another example was problem 8 of the same set concerning five female students running in a race. The initial question was to determine who ran third; however, in order to get better insight on students’ logical processing of the word problem the question was adjusted to: “Who were the first, second, and third to finish the race?”

The numbers used in some word problems were adjusted to control for unnecessary computational challenges since the focus of the word problems is to measure students’ linguistic processing ability rather than evaluating their computational competencies. Furthermore, all word problems, both English and Arabic versions, were solved by the researcher several times to avoid any unforseen problem or unwarranted perplexity that might rise. However, there were two problems for which the problem stated in a language made it easier to understand in one over the other due to the nature of the language or to differing vocabulary in each language. Five mathematics professors have evaluated and approved the word problems with respect to difficulty level and adequacy of concepts targeted by the word problems.

Research Design

The students were randomly divided into four groups: group 1 were given only the English version of the problems for both sets (Eng1/Eng2); group 2 were given the English version for the first set and the Arabic version for the second (Eng1/Ar2); group 3 were given the Arabic version for the first set and the English version for the second (Ar1/Eng2); and group 4 were given only the Arabic version of the problems for both sets (Ar1/Ar2).

To better interpret the results of this study, it was important to evaluate students’ computational skills. To do so, the study included a rubric. The rubric was a four point scale that assigned points for both process and correct answer.

Table 2 The rubric used for assessing student solutions

LEVEL NO.	DESCRIPTION	CHARACTERISTICS
4	The solution offers clear and convincing evidence of deep knowledge of the mathematics.	Solution exhibits correct process and answer.
3	The solution offers evidence of substantial knowledge of the mathematics.	Solution exhibits correct process but minor flaw leading to incorrect answer.
2	The solution offers limited or inconsistent evidence of knowledge of the mathematics.	Solution exhibits incorrect or missing process but the answer is correct.
1	The solution little or no evidence of knowledge of the mathematics.	Solution exhibits wrong answer and wrong process or, wrong answer and no process shown.
0	No attempt was made to solve the problem.	Solution is missing.

Each set of ten word problems were scored based on the rubric where the lowest raw score was 0 and the highest score was 40.

Variables of the Study

1. Independent variable: The only independent variable in this study was the group number each student belonged to which revealed the language of each of set 1 and set 2. The language variable was given the value 0 if the the student solved the problem set in English, and 1 if the the student solved the problem set in Arabic.

2. Covariate variables: There are three covariates used in this study. The first two covariates are the student's standardized score on the Stanford Achievement Test 10 (SAT10) for the reading comprehension and the mathematics problem solving categories. The student's final average in the Arabic language was used as the third covariate to control for the student's level in the Arabic language. About 21 students were classified by the school as either ESL 1 or ESL 2 students, which means they take English as a second language at a level 1 or a higher level 2. These students did not take the SAT10, hence their scores in both the reading comprehension and mathematics problem solving were missing. To compensate for their missing scores, with the approval of the statistical supervisor, they were assigned by the researcher the 25th percentile normalized scaled score in the reading comprehension for the specific grade level of the student in ESL 2 and the 10th percentile normalized scaled score of the student in ESL 1. Only four students left the school before being tested for SAT10, hence they were given the 50th percentile normalized

scaled score in the reading comprehension for their grade level. All of these students were given the 50th percentile normalized scaled score for their grade level in the mathematics problem solving. None of the students were missing their final average in the Arabic language.

3. Dependent variable: The student's total score on set 1 and total score on set 2 were used as the dependent variables in running the statistical tests for this study. This score ranged from 0 to 40, following the rubric selected for this study. A total score of 0 was given to those students in group 2 (Eng1/Ar2) or group 3 (Ar1/Eng2) who explicitly expressed their inability to solve only one of the two sets of word problems due to their lack of proficiency in that particular language. These students were not excluded from the study. Students who were in group 1 (Eng1/Eng2) or group 2 (Ar1/Ar2) and were unable to solve both sets of word problems due to their lack of proficiency in that particular language were excluded from the study. Missing scores on either set 1 or set 2 for other reasons, like absence or departure from school, were left empty.

Data Analysis Procedures

The students in grades 5, 6, and 7 were randomly assigned to one of the four groups (Eng1/Eng2, Eng1/Ar2, Ar1/Eng2, Ar1/Ar2). The covariates were the student's scores on the Stanford 10 standardized test on English comprehension and mathematics problem solving areas, as well as the final grade given to the student at the end of the academic year in the Arabic subject. The dependant variable was the total scores given on set 1 and set 2 of the word problems presented in this study. The independent variable is the group number that the student was randomly assigned to. Group 1 refers to Eng1/Eng2; group 2 refers to Eng1/Ar2; group 3 refers to Ar1/Eng2; and group 4 refers to Ar1/Ar2.

To answer the first research question: "Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students?", two separate statistical tests were performed. A multivariate analysis of covariance (MANCOVA) was conducted where the independent variable is the group number, the dependent variable is the total scores on set 1 and set 2, and the covariates are the SAT10 scores on reading comprehension, SAT10 scores on mathematics problem solving, and the final average in the Arabic school subject. A total of: 3(covariates)×4(groups)×2(posttest measures)=24 cells resulted from this design. A MANOVA was then conducted followed by a Tukey post hoc analysis to support the MANCOVA test and to determine whether group performance varied significantly from each other on set 1 and set 2 respectively and in what direction.

To answer the second question: "Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems?", two types of regression analysis were performed. Multiple regression was conducted first to give an overall picture of how the different groups performed compared to first group (Eng1/Eng 2) and which of the three covariates was most influential in predicting student performance on sets 1 and 2. A simple regression followed by a multiple regression were conducted on four separate subgroups: (1) groups 1 and 2 who performed the English version of set 1; (2) groups 3 and 4 who performed the Arabic version of set 1; (3) groups 1 and 3 who performed the English version of set 2; and (4) groups 2 and 4 who performed the Arabic version of set 2. Arabic was entered as the only predictor in the first model and then the other two covariates (SAT10 scores on reading comprehension and mathematics problem solving) were added to the second model.

To answer the third research question: "What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic?" a frequency table was established for the percentage of students who received each of the possible score value (0, 1, 2, 3, or 4) for each word problem per set per language. Comparisons were made between problems of similar themes across languages for each set and across both sets. I analyzed individual student responses and tallied the types of mistakes and/or procedures exhibited through student responses while keeping track of the language in which they occurred. The researcher also documented all of the remarks and comments written by the students on their test papers.

Research Issues

Reliability

To control for reliability and to decrease the learner effect, group 1 (Eng1/Eng2) and group 4 (Ar1/Ar2) were formed. To further control for the learner effect, testing all students was performed on two different days with a few days gap in between, such as on a Thursday and the following Tuesday.

Internal consistency reliability: A pilot study was done prior to this study where data was collected from 20 students who performed set 1 in Arabic and 25 students who performed set 2 in English. Evaluation of these students was coordinated by the researcher and another native English speaking rater for the English version of set 1 and the researcher and a different native Arabic speaking rater for the Arabic version of set 1 according to the rubric selected for this study. Discussions were held by each of the two raters about any differences in their ratings and a consensus was reached. The Cronbach's Alpha coefficient was calculated for problems 1 through 10 of set 1 and was found to be .70 indicating minimally adequate reliability.

Interrater reliability: 15 test papers were randomly selected from set 1 and 20 test papers were randomly selected from set 2 from each language group for a total of 70 papers. The test papers of sets 1 and 2 in the English language were rated by the researcher and the same native English speaking rater as in the pilot study, and the test papers of sets 1 and 2 in the Arabic language were rated by the researcher and the same native Arabic speaking rater as in the pilot study. The interrater reliability index as measured by intraclass correlation coefficient for the English version was .88 and for the Arabic version was .79. This indicates that there is a high interrater reliability between both pairs of raters.

Equivalent forms reliability: To establish the equivalent form reliability of the two sets of the word problem instrument, the performance of students in group 1 (Eng1/Eng2) and group 4 (Ar1/Ar2) were tested for any variance in performance between set 1 and set 2. The correlation of the performance of students in group 1 (Eng1/Eng2) who performed both sets 1 and 2 in English was computed using the Guttman split-half coefficient and was found to be .93 indicating very high correlation between both sets of the word problems. Similarly, the correlation of the performance of students in group 4 who performed both sets 1 and 2 in Arabic was computed using the Guttman split-half coefficient and was found to be .77 indicating a good correlation between both sets of the word problems but not as high as the English version. This indicates that there is a good level of equivalent forms reliability between sets 1 and 2. Since the two forms have been shown to be highly correlated, then any future variances that may be found between students performing the word problems in different languages may not be attributed to the word problem instrument, but rather explained by the language factor, having controlled for the students' abilities in the reading comprehension, mathematics problem solving and Arabic language. The correlation of the performance of students in group 2 (Eng1/Ar2) on sets 1 and 2 was computed using the Guttman split-half coefficient and was found to be .51. The correlation of the performance of students in group 3 (Ar1/Eng2) on sets 1 and 2 was computed using the Guttman split-half coefficient and was found to be .55. Due to the close affinity between the two values of the Guttman split-half coefficient for groups 2 and 3, the order of language in which the students performed sets 1 and 2 did not affect how well they performed on these two sets.

Validity

This study possesses ecological validity since the methods, materials and setting of the study approximate the real-life situation that is under study. Three professors of mathematics reviewed both sets of word problems at several stages in the design of the study. The themes of the word problems in both sets were verified for compatibility and the numbers used in the word problems were checked for level of difficulty. The three professors approved the word problems of sets 1 and 2, thus establishing the face validity of the word problems instrument.

Conclusion

Methodology of this research will help determine areas in which Arab-American students' comprehension level impact their success in solving mathematical word problems in Arabic or in English. The instrumentation, the research design, and data analysis procedures, all focus on ascertaining the language factors that play a role in Arab-American students' understanding of mathematical word problems.

CHAPTER FOUR

FINDINGS OF THE STUDY

Introduction

In this chapter, the findings of this study are achieved through quantitative statistical analysis, as well as through qualitative analysis of students' processing of the word problems. The quantitative statistical analysis included running descriptive statistics, correlations, MANCOVA, MANOVA, multiple regression, and a combination of four simple regressions, each of which was followed by a multiple regression. The qualitative analysis included detailed discussion of student processing of each word problem within each set in each language version. Discussion of word problem processing was conducted within each of the five word problem categories, which are: "logical reasoning", "x times as many", "fewer than", "think backwards", and "multi-step problem".

This study attempted to answer three research questions. The first two questions were answered using the quantitative statistical analysis, while the last research question was answered using the qualitative analysis. The three research questions are:

4. Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students? Specifically, is there a difference in the performance of Arab-

American students when solving word problems in English compared to solving word problems in Arabic? Null

5. Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems?
6. What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic?

Descriptives

There were 202 students enrolled in grades 5, 6 and 7 in the school participating in the study. 29 students chose not to participate in the study and hence were eliminated. A total of 173 students participated in the study. Table 3 shows an overview distribution of the students with respect to grade level and gender.

Table 3 Distribution of the students with respect to grade level and gender

	Grade 5	Grade 6	Grade 7
Females	27	30	38
Males	29	26	23
Total	56	56	61

Table 4 presents the number of students in each of the four groups with the mean, and standard deviation for each of the three covariates: SAT reading comprehension, SAT mathematics problem solving, and Arabic final grade; and the two dependent variables: set 1 and set 2 totals. A MANCOVA analysis will determine whether the means are significantly different or not.

Table 4 Descriptive statistics of students by group

Group Number		N	Mean	Std. Deviation
(1) Eng1/Eng2	SAT Reading Comprehension	39	650.62	30.611
	SAT Math Problem Solving	39	654.64	32.728
	Arabic Average	39	87.05	9.451
	Pretest Total	38	23.11	9.498
	Posttest Total	39	24.15	8.502
	Valid N (listwise)	38		
(2) Eng1/Ar2	SAT Reading Comprehension	37	663.68	37.330
	SAT Math Problem Solving	37	668.27	40.659
	Arabic Average	37	86.81	9.076
	Pretest Total	37	26.86	7.868
	Posttest Total	35	13.17	10.459
	Valid N (listwise)	35		
(3) Ar1/Eng2	SAT Reading Comprehension	40	656.60	35.841
	SAT Math Problem Solving	40	657.13	31.669
	Arabic Average	40	89.05	7.103
	Pretest Total	39	15.44	8.255
	Posttest Total	39	25.49	7.104
	Valid N (listwise)	38		
(4) Ar1/Ar2	SAT Reading Comprehension	57	656.75	38.477
	SAT Math Problem Solving	57	663.91	35.323
	Arabic Average	57	89.18	7.956
	Pretest Total	55	17.33	8.192
	Posttest Total	55	17.51	8.823
	Valid N (listwise)	53		

Correlations

Table 5 describes the overall correlation for all 173 students of each of the three covariate variables and the two dependent variables with each of the other variables. Overall, SAT reading is highly correlated (.643) with SAT mathematics problem solving. SAT mathematics problem solving is moderately correlated (.436) with Set 1 totals and less moderately correlated (.359) with Set 2 totals. The Arabic average did not correlate highly with any of the other two covariates. Although all of the other correlations are significant, none is greater than .40.

Table 5 Overall correlation of variables

		SAT Reading Comprehension	SAT Math Prob. Solving	Arabic Average	Set 1 Total	Set 2 Total
SAT Reading Comprehension	Pearson Correlation	1	.643(**)	.151(*)	.336(**)	.266(**)
	Sig. (2-tailed)		.000	.047	.000	.000
	N	173	173	173	169	168
SAT Math Problem Solving	Pearson Correlation	.643(**)	1	.230(**)	.436(**)	.359(**)
	Sig. (2-tailed)	.000		.002	.000	.000
	N	173	173	173	169	168
Arabic Average	Pearson Correlation	.151(*)	.230(**)	1	.159(*)	.297(**)
	Sig. (2-tailed)	.047	.002		.039	.000
	N	173	173	173	169	168
Set 1 Total	Pearson Correlation	.336(**)	.436(**)	.159(*)	1	.326(**)
	Sig. (2-tailed)	.000	.000	.039		.000
	N	169	169	169	169	164
Set 2 Total	Pearson Correlation	.266(**)	.359(**)	.297(**)	.326(**)	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	168	168	168	164	168

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 6 presents the correlations between the three covariates (SAT reading comprehension, SAT mathematics problem solving, and Arabic average) and the two dependant variables (DVs: set 1 total, and set 2 total), but for each group separately. Results from table 6 show:

1. SAT reading comprehension is highly correlated with SAT mathematics problem solving across the four different groups, which is consistent with the overall high correlation reported in Table 3. SAT reading comprehension is also highly correlated with set 1 totals, and set 2 totals for group 1 (Eng1/Eng2), moderately high (.475) with set 1 totals for group 2 (Eng1/Ar2), and moderately high (.529) with set 2 totals for group 3 (Ar1/Eng2). Hence, it was found that SAT reading comprehension is moderately to highly correlated with student performance when solving problems in the English language.
2. SAT mathematics problem solving is also highly correlated with set 1 totals and set 2 totals when they are performed in the English language, but moderately correlated with set 2 totals (.466) for group 3 (Ar1/Eng2). On the other hand, all correlations of SAT mathematics problem solving with set 1 totals and set 2 totals were low (<.40) when performed in the Arabic language. Group 2 (Eng1/Ar2) was the exception with correlation of .580. Hence, the correlation of SAT mathematics problem solving with student performance when solving problems in the Arabic version was low.

3. The correlation of Arabic final grade with set 1 and set 2 totals seem to be moderate (.429) to low moderate (<.40) when the problems are done in Arabic.
4. Set 1 totals were highly correlated with Set 2 totals when the language of both sets was the same: group 1 (Eng1/Eng2) (.838); group 4 (Ar1/Ar2) (.591). There is a moderate correlation between set 1 and set 2 totals for group 3 (Ar1/Eng2) (.431).

Table 6 Correlations of variables within each group

Group Number			SAT Reading Comprehen-sion	SAT Math Problem Solving	Arabic Average	Set 1 Total	Set 2 Total
(1) Eng1/Eng2	SAT Reading Compr.	Pearson Correlation	1	.638(**)	.117	.711(**)	.692(**)
		Sig. (2-tailed)		.000	.480	.000	.000
		N	39	39	39	38	39
	SAT Math Prob. Solving	Pearson Correlation	.638(**)	1	.331(*)	.696(**)	.644(**)
		Sig. (2-tailed)	.000		.039	.000	.000
		N	39	39	39	38	39
	Arabic Average	Pearson Correlation	.117	.331(*)	1	.231	.395(*)
		Sig. (2-tailed)	.480	.039		.162	.013
		N	39	39	39	38	39
	Set 1 Total	Pearson Correlation	.711(**)	.696(**)	.231	1	.838(**)
		Sig. (2-tailed)	.000	.000	.162		.000
		N	38	38	38	38	38
	Set 2 Total	Pearson Correlation	.692(**)	.644(**)	.395(*)	.838(**)	1
		Sig. (2-tailed)	.000	.000	.013	.000	
		N	39	39	39	38	39
(2) Eng1/Ar2	SAT Reading Compr.	Pearson Correlation	1	.636(**)	.240	.475(**)	.198
		Sig. (2-tailed)		.000	.152	.003	.254
		N	37	37	37	37	35
	SAT Math Prob. Solving	Pearson Correlation	.636(**)	1	.445(**)	.752(**)	.580(**)
		Sig. (2-tailed)	.000		.006	.000	.000
		N	37	37	37	37	35
	Arabic Average	Pearson Correlation	.240	.445(**)	1	.337(*)	.429(*)
		Sig. (2-tailed)	.152	.006		.041	.010
		N	37	37	37	37	35
	Set 1 Total	Pearson Correlation	.475(**)	.752(**)	.337(*)	1	.368(*)
		Sig. (2-tailed)	.003	.000	.041		.029
		N	37	37	37	37	35
	Set 2 Total	Pearson Correlation	.198	.580(**)	.429(*)	.368(*)	1
		Sig. (2-tailed)	.254	.000	.010	.029	
		N	35	35	35	35	35

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 6 (Continued)

Group Number			SAT Reading Comprehen-sion	SAT Math Problem Solving	Arabic Average	Set 1 Total	Set 2 Total
(3) Ar1/Eng2	SAT Reading Compr.	Pearson Correlation	1	.650(**)	.103	-.076	.529(**)
		Sig. (2-tailed)		.000	.526	.644	.001
		N	40	40	40	39	39
	SAT Math Prob. Solving	Pearson Correlation	.650(**)	1	.070	.102	.466(**)
		Sig. (2-tailed)	.000		.668	.537	.003
		N	40	40	40	39	39
	Arabic Average	Pearson Correlation	.103	.070	1	.087	-.028
		Sig. (2-tailed)	.526	.668		.598	.865
		N	40	40	40	39	39
	Set 1 Total	Pearson Correlation	-.076	.102	.087	1	.431(**)
		Sig. (2-tailed)	.644	.537	.598		.007
		N	39	39	39	39	38
	Set 2 Total	Pearson Correlation	.529(**)	.466(**)	-.028	.431(**)	1
		Sig. (2-tailed)	.001	.003	.865	.007	
		N	39	39	39	38	39
(4) Ar1/Ar2	SAT Reading Compr.	Pearson Correlation	1	.641(**)	.156	.374(**)	.161
		Sig. (2-tailed)		.000	.247	.005	.240
		N	57	57	57	55	55
	SAT Math Prob. Solving	Pearson Correlation	.641(**)	1	.083	.323(*)	.310(*)
		Sig. (2-tailed)	.000		.539	.016	.021
		N	57	57	57	55	55
	Arabic Average	Pearson Correlation	.156	.083	1	.307(*)	.349(**)
		Sig. (2-tailed)	.247	.539		.023	.009
		N	57	57	57	55	55
	Set 1 Total	Pearson Correlation	.374(**)	.323(*)	.307(*)	1	.591(**)
		Sig. (2-tailed)	.005	.016	.023		.000
		N	55	55	55	55	53
	Set 2 Total	Pearson Correlation	.161	.310(*)	.349(**)	.591(**)	1
		Sig. (2-tailed)	.240	.021	.009	.000	
		N	55	55	55	53	55

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

MANCOVA Results

The three covariates used in this statistical test are SAT reading comprehension score, SAT mathematics problem solving score, and final grade average for Arabic. As reported in Table 4, the intercorrelations between the Arabic final grade with each of the SAT reading comprehension and the SAT mathematics problem solving scores are .15 and .23 respectively, which are considered to be low (<.40). However, the intercorrelation between the SAT reading comprehension and the SAT mathematics problem solving scores was .64, which is considered to be relatively high. The MANCOVA test is used to answer the question of whether there are significant mean differences in student performance for students in group 1 (Eng1/Eng2), group 2 (Eng1/Ar2), group 3 (Ar1/Eng2), and group 4 (Ar1/Ar2), after controlling for their levels in English comprehension, mathematics problem solving and Arabic competence. The following assumptions for MANCOVA were checked for:

(a) independence of observations: The assumption of independence of observations was met since students worked individually on solving set 1 and set 2 on two separate days within a natural classroom setting. Furthermore, the two sets of word problems are composed of 10 word problems that are distinct from each other yet comparable in content.

(b) normal distribution of the dependent variables: The normal distribution of the dependent variables was assessed through a scatter plot of predicted variable versus Standard Residual. The assumption of normality for both dependent variables is met.

(c) homogeneity of variances: Box's Test indicates that the assumption of homogeneity of variance-covariance has not been met, $F(9,214506.5)= 2.801$, $p=.003$. Since group sizes are fairly comparable, the F statistic is robust against heterogeneous variances (Stevens, 2002), thus this violation was not a problem.

(d) linear relationships between the covariates and the dependent variable: The linearity of the two DVs (set1 and set 2 totals) and the covariates (SAT English reading comprehension, SAT mathematics problem solving, Arabic final grade) was tested by calculating the Pearson correlation coefficients. Although all of the correlation coefficients calculated are statistically significant, all are quite low except for the correlation between reading comprehension and mathematics problem solving. Finally, the correlation between scores on set 1 and set 2 is .33 which is considered small (<.40).

(e) homogeneity of regression slopes: Levene's test of equality of error variances shows that the assumption of homogeneity of variances has been met for set 1 [$F(3,160)=2.417$, $p=.068$] and set 2 [$F(3,160)=1.345$, $p=.262$] totals.

Wilks' Lambda was used as the multivariate statistic. Wilk's Lambda indicates heterogeneity of variance for two of the three covariates: SAT mathematics problem solving (Wilk's Λ=.859, $F(2, 156)=12.844$, $p<.001$, multivariate η^2=.141) and Arabic final grade (Wilk's Λ=.940, $F(2, 156)=4.969$, $p=.008$, multivariate η^2=.060), meaning that only the mathematics and Arabic achievement covariates have a highly significant effect on students' performance on sets 1 and 2. The SAT reading comprehension scores was not significant in explaining variation in student performance on sets 1 and 2 (Wilk's Λ=.991, $F(2, 156)=.733$, $p=.482$, multivariate η^2=.009).

Table 7 Adjusted And Unadjusted Means For Set 1 And Set 2 Totals By Group Category Using The Covariates SAT Reading Comprehension Scores, SAT Mathematics Problem Solving Scores, And Arabic Final Average As Covariates

	Set 1 Totals		Set 2 Totals	
Group	Adjusted M	Unadjusted M	Adjusted M	Unadjusted M
Eng1/Eng2	23.90 (1.20)	23.11 (9.50)	24.90 (1.20)	24.03 (8.58)
Eng1/Ar2	25.79 (1.25)	26.17 (7.51)	12.91 (1.26)	13.17 (10.46)
Ar1/Eng2	15.32 (1.20)	15.16 (8.18)	25.81 (1.20)	25.66 (7.12)
Ar1/Ar2	16.74 (1.01)	17.17 (8.18)	16.74 (1.02)	17.30 (8.28)

Both the adjusted and unadjusted means of the students who performed the word problems in the English language are higher than the adjusted and unadjusted means of the students who performed the word problems in the Arabic language. From the results presented in Table 8, the separate

ANCOVA results show that the covariate, SAT mathematics problem solving, is the only covariate that has a significant effect on both set1 and set 2 totals.

Table 8 ANCOVA Summary Table for Set 1 and Set 2 Totals as a Function of Group Membership, Using SAT Reading Comprehension Scores, SAT Mathematics Problem Solving Scores, And Arabic Final Average As Covariates

Source	Dependent Var.	SS	df	MS	F	p	η^2
SAT Reading	Set 1 Totals	79.06	1	79.06	1.47	.227	.009
	Set 2 Totals	17.56	1	17.56	.32	.571	.002
SAT Math	Set 1 Totals	865.48	1	865.48	16.10	<.001	.093
	Set 2 Totals	1104.70	1	1104.70	20.29	<.001	.114
Arabic Average	Set 1 Totals	205.32	1	205.32	3.82	.052	.024
	Set 2 Totals	513.98	1	513.98	9.44	.003	.057
Group No.	Set 1 Totals	3069.94	3	1023.31	19.04	<.001	.267
	Set 2 Totals	4440.36	3	1480.12	27.19	<.001	.342
Error	Set 1 Totals	8439.26	157	53.75			
	Set 2 Totals	8546.28	157	54.44			

Computed using alpha = .05

Univariate ANCOVA results indicate that the DV of set1 total was significantly effected by the covariate of SAT mathematics problem solving ($F(1,157)=16.10$, $p<.001$, partial $\eta^2=.093$); and was approaching significance with the covariate of Arabic final grade ($F(1, 157)=3.82$,

$p=.052$, partial $\eta^2=.024$). However the third covariate of SAT reading ($F(1,157)=1.47$, $p=.227$, partial $\eta^2=.009$) was not significant.

Univariate ANCOVA results indicate that the DV of set 2 total is significantly affected by the SAT mathematics problem solving covariate ($F(1,157)=20.29$, $p<.001$, partial $\eta^2=.114$) and by the Arabic final grade covariate ($F(1,157)=9.44$, $p=.003$, partial $\eta^2=.057$). Again, SAT reading played no significant role in explaining variances in student performance on set 2 ($F(1, 157)=.32$, $p=.571$, partial $\eta^2=.002$).

MANOVA Results

A multivariate analysis of variance was conducted to assess if there were differences between the four groups (Eng1/Eng2, Eng1/Ar2, Ar1/Eng2, Ar1/Ar2) on set 1 and set 2 scores. The correlation between set 1 and set 2 totals is significant but moderate ($r=.326$). Box's test of equality of covariance matrices shows that the assumption of homogeneity of covariances is violated ($F(9,214506.5)=2.801$, $p=.003$), however, since the group sizes (38, 35, 38, and 53) are relatively similar, this was not a problem. A significant difference was found among the four groups, Wilk's $\Lambda=.454$, $F(6, 318)=25.031$, $p<.001$, multivariate $\eta^2=.327$ (high effect size). The effect size is the measure of strength of association which is interpreted as the proportion of variance in the dependent variable (student performance on set 1 and set 2) explained by the independent variable (group number) in the sample (Mertler & Vannatta, 2005). Levene's test of equality or error variances has been met for both dependent variables; Set 1: $F(3, 160) = 1.527$, $p=.210$, and Set 2: $F(3, 160) = 1.654$, $p=.179$.

Table 9 Adjusted Means For Set 1 And Set 2 Totals By Group Number

		Set 1 Totals		Set 2 Totals	
Group No.	N	Adjusted M	SD	Adjusted M	SD
1 (Eng1/Eng2)	38	23.11	1.36	24.03	1.40
2 (Eng1/Ar2)	35	26.17	1.41	13.17	1.46
3 (Ar1/Eng2)	38	15.16	1.36	25.66	1.40
4 (Ar1/Ar2)	53	17.17	1.15	17.30	1.18

The separate ANOVA results shown in Table 10 reveals a significant main effect for group membership on student performance. The univariate ANOVA results show that both set 1 totals ($F(3,160)=14.353$, $p<.001$), and set 2 totals ($F(3,160)=17.281$, $p<.001$), when examined separately, contributed to distinguishing the four groups.

Table 10 Effects of Group Number on Set 1 and Set 2 Totals

Source	Dependent Variable	df	F	p	η^2
Group Number	Set 1 Total	3	14.35	<.001	.212
	Set 2 Total	3	17.28	<.001	.245
Error	Set 1 Total	160			
	Set 2 Total	160			

Computed using alpha = .05

Furthermore, Table 11 shows that group 1 (Eng1/Eng2) (β=5.94, p=.001, multivariate η^2=.065) and group 2 (Eng1/Ar2) (β=9.00, p<.001, multivariate η^2=.132) did significantly better than the other two groups on set 1; group 1 (Eng1/Eng2) (β=6.72, p<.001, multivariate η^2=.078) and group 3 (Ar1/Eng2) (β=8.36, p<.001, multivariate η^2=.115) did significantly better than group 4 (Ar1/Ar2), but group 2 (Eng1/Ar2) (β=-4.13, p=.029, multivariate η^2=.029) did significantly worse than group 4(Ar1/Ar2) on set 2. Hence, as shown by the univariate ANOVAs, students who solved the word problems in English performed significantly better than those students who solved the word problems in Arabic for both sets 1 and 2.

Table 11 Parameter Estimates as a result of MANOVA

Dependent Variable	Parameter	B	Std. Error	t	Sig.	Partial Eta Squared	Observed Power[a]
Set 1 Total	Intercept	17.170	1.149	14.938	.000	.582	1.000
	[GrpNo=1]	5.935	1.779	3.337	.001	.065	.913
	[GrpNo=2]	9.002	1.823	4.939	.000	.132	.998
	[GrpNo=3]	-2.012	1.779	-1.131	.260	.008	.203
	[GrpNo=4]	0[b]	.	.	.	.	.
Set 2 Total	Intercept	17.302	1.184	14.618	.000	.572	1.000
	[GrpNo=1]	6.724	1.832	3.671	.000	.078	.954
	[GrpNo=2]	-4.130	1.877	-2.201	.029	.029	.590
	[GrpNo=3]	8.356	1.832	4.562	.000	.115	.995
	[GrpNo=4]	0[b]	.	.	.	.	.

a. Computed using alpha = .05

b. This parameter is set to zero because it is redundant.

Examination of post hoc results confirm these findings as shown in table 12. Basically, the post hoc confirms that students who solved the word problems in the English language performed significantly better than students who solved the word problems in the Arabic language in both sets.

Table 12 Post Hoc multiple comparison of groups using Tukey

Tukey HSD

Dependent Variable	(I) Group Number	(J) Group Number	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Set 1 Total	Eng/Eng	Eng/Ar	-3.07	1.960	.402	-8.16	2.02
		Ar/Eng	7.95*	1.920	.000	2.96	12.93
		Ar/Ar	5.94*	1.779	.006	1.32	10.55
	Eng/Ar	Eng/Eng	3.07	1.960	.402	-2.02	8.16
		Ar/Eng	11.01*	1.960	.000	5.92	16.10
		Ar/Ar	9.00*	1.823	.000	4.27	13.73
	Ar/Eng	Eng/Eng	-7.95*	1.920	.000	-12.93	-2.96
		Eng/Ar	-11.01*	1.960	.000	-16.10	-5.92
		Ar/Ar	-2.01	1.779	.671	-6.63	2.61
	Ar/Ar	Eng/Eng	-5.94*	1.779	.006	-10.55	-1.32
		Eng/Ar	-9.00*	1.823	.000	-13.73	-4.27
		Ar/Eng	2.01	1.779	.671	-2.61	6.63
Set 2 Total	Eng/Eng	Eng/Ar	10.85*	2.019	.000	5.61	16.10
		Ar/Eng	-1.63	1.977	.842	-6.76	3.50
		Ar/Ar	6.72*	1.832	.002	1.97	11.48
	Eng/Ar	Eng/Eng	-10.85*	2.019	.000	-16.10	-5.61
		Ar/Eng	-12.49*	2.019	.000	-17.73	-7.25
		Ar/Ar	-4.13	1.877	.127	-9.00	.74
	Ar/Eng	Eng/Eng	1.63	1.977	.842	-3.50	6.76
		Eng/Ar	12.49*	2.019	.000	7.25	17.73
		Ar/Ar	8.36*	1.832	.000	3.60	13.11
	Ar/Ar	Eng/Eng	-6.72*	1.832	.002	-11.48	-1.97
		Eng/Ar	4.13	1.877	.127	-.74	9.00
		Ar/Eng	-8.36*	1.832	.000	-13.11	-3.60

Based on observed means.

*. The mean difference is significant at the .05 level.

Multiple Regression Results

Which of the three covariates (i.e. SAT reading comprehension, SAT mathematics problem solving, or Arabic final grade) are most influential in predicting student performance scores on sets 1 and 2? The correlation matrix of Table 4 shows that there is a high correlation between reading comprehension and mathematics problem solving ($r=.646$). All other correlations are minimal ($r=.150$, between Arabic final grade and SAT reading comprehension) to moderate ($r=.436$, between SAT mathematics and set 1 totals). Regression results indicate that the overall model significantly predicts student's performance on set 1 ($R^2= .408$, $R^2_{adj}= .386$, $F(6,162)=18.570$, $p<.001$) and on set 2 ($R^2= .448$, $R^2_{adj}= .428$, $F(6,161)=21.791$, $p<.001$). The adjusted R square indicates that the model is quite good, explaining 39% of the variance in student's performance on set 1 and 43% of the variance in student's performance on set 2. A summary of regression coefficients is presented in tables 13 and 14 and indicates that only SAT mathematics problem solving score and Arabic final average significantly contributed to the model for both sets 1 and 2. Moreover, it is worth noting that the only tolerance value that is closest to 1 was the Arabic final average for both set 1 (.924) and set 2 (.929). Tolerance is the proportion of the variability of one predictor that is not explained by the other predictors in the equation (Vogt, 2007). Hence, there is no problem of multicollinearity between the Arabic final Average and the SAT reading comprehension and mathematics problem solving.

Table 13 Coefficients for Model Variable Set 1, Using Group 1 as the Reference

	B	SEB	β	t	p	Bivariate r	Partial r
Grp 2	2.279	1.733	.100	1.315	.190	.369	.103
Grp 3	-8.267	1.703	-.369	-4.855	<.001	-.281	-.356
Grp 4	-6.943	1.579	-.344	-4.399	<.001	-.217	-.327
Reading Compr.	.025	.021	.097	1.217	.226	.336	.095
Math Pr. Solv.	.086	.022	.320	3.945	<.001	.436	.296
Arabic Final Gr.	.147	.071	.130	2.065	.040	.159	.160

Computed using alpha = .05

Table 14 Coefficients for Model Variable Set 2, Using Group 1 as the Reference

	B	SEB	β	t	p	Bivariate r	Partial r
Grp 2	-12.109	1.759	-.498	-6.884	<.001	-.354	-.477
Grp 3	.502	1.708	.021	.294	.769	.305	.023
Grp 4	-8.212	1.583	-.390	-5.188	<.001	-.176	-.378
Reading Compr.	.013	.021	.045	.595	.553	.266	.047
Math Pr. Solv.	.099	.022	.352	4.533	<.001	.359	.336
Arabic Final Gr.	.230	.071	.196	3.219	.002	.297	.246

Computed using alpha = .05

The beta weights, presented in the Tables 13 and 14, suggest that students who solved the Arabic version of both sets 1 and 2 performed significantly lower than students who solved the English version.

Regression Results

To investigate how well Arabic final grade predict student performance on the different linguistic versions of sets 1 and 2 while controlling for students' reading comprehension and mathematical problem solving abilities, a two model multiple regression was repeatedly run on the data on set 1 English version only, on set 1 Arabic version only, on set 2 English version only, and on set 2 Arabic version only. Results will be discussed separately and then an overall summation will be presented.

a. Set 1 English version only: This set consisted of all students in groups 1 and 2 who took the English version of set 1. When Arabic was entered alone, it significantly predicted student's performance on the English version of set 1, $F(1,73)=5.747$, $p=.019$, adjusted $R^2=.06$. This means that only 6% of the variance in student performance on the English version of set 1 could be predicted by knowing the student's final grade in Arabic. When the other variables were added (SAT reading comprehension score and SAT mathematics problem solving score), they significantly improved the prediction, R^2 change $=.47$, $F(2,71)=37.143$, $p<.001$. The entire group of variables significantly predicted students performance, $F(3,71)=28.575$, $p<.001$, adjusted $R^2=.53$.
A summary of the regression model is presented in Table 15.

Table 15 Simple and Multiple Regression Analysis Summary for Predicting English Version of Set 1 Totals

Model	B	SEB	β	t	p	R^2	ΔR^2
1. Arabic FG	.260	.109	.270	2.397	.019	.073	.073
2. Arabic FG	.010	.084	.010	.114	.910	.547	.474
Reading Compr.	.058	.028	.225	2.094	.040		
Math Pr. Solv.	.135	.027	.568	4.945	<.001		

Computed using alpha = .05

The Beta weights, presented in Table 13, suggest that, when controlling for student's levels in reading comprehension and mathematics problem solving, Arabic final grade is no longer a significant predictor. Moreover, while both SAT mathematics problem solving and SAT reading comprehension scores contribute significantly to the student's performance on the English version, SAT mathematics problem solving contributes the most.

b. <u>Set 1 Arabic version only</u>: This set consisted of all students in groups 3 and 4 who took the Arabic version of set 1. When Arabic was entered alone, it significantly predicted student's performance on the Arabic version of set 1, $F(1,92)=4.826$, $p=.031$, adjusted $R^2=.040$. This means that only 4% of the variance in student performance on the Arabic version of set 1 could be predicted by knowing the student's final grade in Arabic. When the other variables were added (SAT reading comprehension score and SAT mathematics problem solving score), they did not make a significant improvement in prediction, R^2 change =.05, $F(2,90)=2.604$, $p=.080$. The entire group of variables significantly predicted students performance, $F(3,90)=3.401$, $p=.021$, adjusted $R^2=.072$.

Table 16 Simple and Multiple Regression Analysis Summary for Predicting Arabic Version of Set 1 Totals

Model	B	SEB	β	t	p	R^2	ΔR^2
1. Arabic FG	.243	.111	.223	2.197	.031	.050	.050
2. Arabic FG	.221	.110	.203	2.009	.048	.102	.052
Reading Compr.	.007	.029	.030	.230	.819		
Math Pr. Solv.	.051	.032	.208	1.603	.112		

Computed using alpha = .05

The Beta weights, presented in Table 16, suggest that, when controlling for student's levels in reading comprehension and mathematics problem solving, Arabic final grade is the only significant predictor of student performance on the Arabic version of set 1, while both SAT mathematics problem solving and SAT reading comprehension scores are not significant predictors of the students' performance.

c. Set 2 English version only: This set consisted of all students in groups 1 and 3 who took the English version of set 2. When Arabic was entered alone, it significantly predicted student's performance on the English version of set 2, $F(1,76)=4.582$, p=.036, adjusted R^2=.044. This means that only 4% of the variance in student performance on the English version of set 2 could be predicted by only knowing the student's final grade in Arabic. When the other variables were added, specifically SAT reading comprehension score and SAT mathematics problem solving score, they significantly improved prediction of student performance, as evident by the R^2 change =.38, $F(2,74)=24.805$, $p<.001$. The entire group of variables significantly predicted students performance, $F(3,74)=19.021$, $p<.001$, adjusted R^2=.41.

Table 17 Simple and Multiple Regression Analysis Summary for Predicting English Version of Set 2 Totals

Model	B	SEB	β	t	p	R^2	ΔR^2
1. Arabic FG	.222	.104	.238	2.141	.036	.057	.057
2. Arabic FG	.123	.083	.132	1.474	.145	.435	.379
Reading Compr.	.099	.027	.423	3.701	<.001		
Math Pr. Solv.	.064	.028	.262	2.253	.027		

Computed using alpha = .05

The Beta weights, presented in table 17, suggest that, when controlling for student's levels in reading comprehension and mathematics problem solving, Arabic final grade is no longer a significant predictor. Both SAT reading comprehension scores and SAT mathematics problem solving contributed significantly to predicting the student's performance on the English version of set 2.

d. Set 2 Arabic version only: This set consisted of all students in groups 2 and 4 who took the Arabic version of set 2. When Arabic was entered alone, it significantly predicted student's performance on the Arabic version of set 2, $F(1,88)=17.345$, $p<.001$, adjusted $R^2=.16$. This means that 16% of the variance in student performance on the Arabic version of set 2 could be predicted by just knowing the student's final grade in Arabic. When the other variables were added (SAT reading comprehension score and SAT mathematics problem solving score), the model was still significant, even though the omnibus F statistic showed to be smaller in value. R^2 change =.14, $F(2,86)=8.265$, $p=.001$. The entire group of variables significantly predicted students performance, $F(3,86)=12.246$, $p<.001$, adjusted $R^2=.28$.

Table 18 Simple and Multiple Regression Analysis Summary for predicting Arabic version of Set 2 Totals

Model	B	SEB	β	t	p	R^2	ΔR^2
1. Arabic FG	.460	.111	.406	4.165	<.001	.165	.165
2. Arabic FG	.379	.105	.334	3.590	.001	.299	.135
Reading Compr.	-.051	.030	-.198	-1.695	.094		
Math Pr. Solv.	.121	.031	.466	3.955	<.001		

Computed using alpha = .05

The Beta weights, presented in Table 18, suggest that, when controlling for students' levels in reading comprehension and mathematics problem solving, both Arabic final grade and SAT mathematics problem solving score are the significant predictors of student performance on the Arabic version of set 2, with mathematics problem solving being a slightly stronger predictor. SAT reading comprehension scores did not play any significant role in predicting student's performance in the Arabic version.

Summary of Quantitative Results

To answer the first research question:

> "Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students?"

a MANCOVA, MANOVA, and multiple regression were run on the data. MANCOVA and the multiple regression tests showed that SAT mathematics problem solving and Arabic final average were the only two covariates significant in explaining variance in student performance on set 1 and set 2. The results from the multiple regression analysis confirmed those of MANOVA and the Post Hoc tests. The statistical tests indicated that on set 1, group 1 (Eng1/Eng2) and group 2 (Eng1/Ar2) performed significantly better than group 3 (Ar1/Eng2) and group 4 (Ar1/Ar2) and on set 2, group 1 (Eng1/Eng2) and group 3 (Ar1/Eng2) performed significantly better than group 2 (Eng1/Ar2) and group 4 (Ar1/Ar2). In sum, all of the three tests confirmed that students performed significantly better on the English version of set 1 and set 2 than on the Arabic version.

To answer the second research question:

> "Do Arab-American students with higher levels of Arabic proficiency perform better in either or both version of the word problems?"

a simple and a multiple regression was run four separate times with Arabic final grade being the only predictor variable, and then adding SAT reading comprehension and SAT mathematics problem solving as additional predictors on the following groups:

1. students who performed the English version of set 1, that is, group1 (Eng1/Eng2) and group 2 (Eng1/Ar2);
2. students who performed the Arabic version of set 1, that is, group 3 (Ar1/Eng2) and group 4 (Ar1/Ar2);
3. students who performed the English version of set 2, that is, group1 (Eng1/Eng2) and group 3 (Ar1/Eng2;)
4. students who performed the Arabic version of set 2, that is, group 2 (Eng1/Ar2) and group 4 (Ar1/Ar2.)

Thus, Arabic final average was significant in predicting student performance on the Arabic and the English version of set 1 and set 2. As for the English version of set 1 and set 2, its prediction power became insignificant when SAT reading comprehension and SAT mathematics problem solving were added as predictors for student performance. This analysis was the only one resulting in SAT reading comprehension being a significant predictor of student performance on the English version of set 1 and set 2. SAT mathematics problem solving was a significant predictor of student performance on all except for the Arabic version of set 1.

Word Problems Processing Analysis

This section analyzes students processing of the problem to determine the answer to the third research question:

> "What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic."

Frequency table 19 was constructed to show the percent of students who received either a '0' or '1' versus a '3' or '4' on each word problem per language within each set. As a reminder, based on the rubric, a student who received a '0' meant that no attempt was made to solve the problem; and a student who received a '1' meant that the student's solution exhibited wrong answer and wrong process or, wrong answer and no process shown. On the other hand, a student who received a '3' meant that the student's solution exhibited correct process but minor flaw leading to incorrect answer or no answer to the problem; and a student who received a '4' meant that the student's solution exhibited correct process and answer to the problem. Success is measured by the sum of the percent of students who received either a '3' or a '4' on the rubric, whereas failure is measured by those who received either a '0' or a '1' on the rubric. A student who received a '2' meant that the students' solution exhibited incorrect or missing process but the answer to the problem is correct. The percent of students who received a '2' score on the rubric were not reported, because it is hard to tell whether a student actually worked on the solution mentally, but failed to show the procedure or simply copied the answer from another student. The table shows results for percent of failures (scores of 0,1) and successes (scores of 3,4).

Table19 Total Percentage of Students Who Received Either a Score Of 0/1 (Failure), or 3/4 (Success) on Each Word Problem Based on the Rubric.

	SET 1 (%)					SET 2 (%)				
CATEGORY	Word Prob.	ENGLISH		ARABIC		Word Prob.	ENGLISH		ARABIC	
		0,1	3,4	0,1	3,4		0,1	3,4	0,1	3,4
1. Logical Reasoning	2	22	40	33	37	7	50	46	69	21
1. Logical Reasoning	8	32	55	49	31	1	8	62	41	33
2. "twice as"	1	13	85	51	42	2	20	72	62	28
2. "four/three times as"	9	68	29	73	22	6	37	57	63	29
3. "fewer than"	5	25	67	47	40	5	31	63	48	44
3. "fewer than"	10	33	66	87	12	9	26	60	70	18
4. "think backwards"	7	54	42	72	17	3	64	30	76	14
4. "think backwards"	4	20	74	41	53	8	19	77	48	49
5. Multi-step problem	3	60	39	73	22	4	49	18	77	5
5. Multi-step problem	6	64	36	87	11	10	77	20	87	10

Overview of Scores Below 10% and Above 90%

An overview of students who scored 10% or lower (i.e. received a score of 4 or lower out of 40) in either language follows:

1. Arabic: In set 1, eight students (8.5%) received a total score of 4 or less; out of those, two students (2.1%) received a total score of 0. In set 2, nine students (10.0%) received a total score of 4 or less; out of those, six students (6.4%) received a total score of 0. A student received a total score of 0 on either tests if they have indicated inability to solve the problems due to lack of adequate knowledge of the language. Thus, 17 students scored 4 or less in the Arabic version.
2. English: None of the students received 4 or less on the English version of either set 1 or set 2. The lowest score on set 1 was a 7 out of 40 and on set 2 was a 9 out of 40.

On the other hand, an overview of students who scored 90% or higher (i.e. received 36 or higher out of 40) shows the following:

1. Arabic: Only one student (1.1%) on set 1 and three students (3.3%) on set 2 received a score of 36 or above out of 40. Of those, only one student (1.1%) received a score of 40 out of 40 on set 2 totals. None of the students received a score of 40 out of 40 on set 1 totals.
2. English: In set 1, twelve students (16.1%) received a score of 36 or above out of 40; of those, two students (2.7%) on set 1 received a score of 40 out of 40. In set 2, eight students (10.3%) received a score of 36 or above out of 40; of those, 1 student (1.3%) received a score of 40 out of 40.

To summarize, Table 19 lists the two problems within each set that belong to the same category. It shows that without exception, the percent of students who received a ‘0’ or ‘1’ on each problem solved in the English version, is lower to a varying degree than the percent of students who performed the same problems in the Arabic language. Similarly, and without exception, the percent of students who received a ‘3’ or ‘4’ on each problem solved in the English version is higher to a varying degree than the percent of students who performed the same problems in the Arabic language.

Detailed discussion of similarities and differences of students’ processing of the problems within each category in both sets in each language follows. Note that consideration of students who received a ‘4’ is omitted since they made no errors.

Discussion of Category 1 problems: Logical Reasoning

Table 20 Total Percentage of Students Who Received Either a Score Of 0/1 (Failure), or 3/4 (Success) on Each Word Problem in the “Logical Reasoning” Category Based on the Results from Table 19.

	SET 1 (%)					SET 2 (%)				
CATEGORY	Word Prob.	ENGLISH		ARABIC		Word Prob.	ENGLISH		ARABIC	
		0,1	3,4	0,1	3,4		0,1	3,4	0,1	3,4
1. Logical Reasoning	**2**	22	40	33	37	**7**	50	46	69	21
1. Logical Reasoning	**8**	32	55	49	31	**1**	8	62	41	33

As seen from Table 20, students’ success rate on problem 2 of set 1 is similar in both languages: English (40%), Arabic (37%). For problem 8 of set 1, the ratio of students who received a 3/4 to those who received a 0/1 in the

English version is 55:32; where as the same ratio in the Arabic version is reversed (31:49). For problem 7 of set 2, the ratio of success to failure was almost 1 to 1 (50:46) in the English version, while it was 1 to 3½ (20:70) for the Arabic version which shows a bigger gap in performance. For problem1 of set 2, while 62% of students solved the problem correctly in English and 8% were unsuccessful, only 33% of the students were successful in Arabic while 41% were unsuccessful. Almost double the percent of students successfully solved the English version than the Arabic version of problem 8 of set 1, problem 7 and problem 1 of set 2.

Table 21 shows the two word problems that fall under the "logical reasoning" category from each set.

Table 21 **"**Logical Reasoning" Word Problems

Category 1: Logical Reasoning	
Set 1	**Set 2**
2. Four friends are measuring their heights. Sharon is shorter than Jenny. <u>Jenny is taller than Bobby but shorter than Sammy</u>. Who is the tallest?	**7.** Michael planted apple, plum, cherry and pear trees in rows. The apple trees are the closest trees to the pear trees. The apple trees are to the right of the cherry trees, and the plum trees are to the left. What is the order of the trees from left to right?

Table 21 (Continued)

CATEGORY 1: LOGICAL REASONING	
SET 1	**SET 2**
8. Lynn, Francine, Eileen, Susan, and Nancy ran in a race. Susan finished the race before Nancy. <u>Francine finished before Susan but after Eileen</u>. Lynn finished before everyone but Eileen. Who was the first, second, and third to finish the race?	**1.** Five students stood in line to go on the school bus. Nicole stood first in line; Lara stood between Sarah and Ron; and Sarah stood behind Nicole. Where does Samantha stand in line?

Characteristics of Students' Processing of Problems:

Logical reasoning: problem 2 and 8 of set 1

- A common mistake in both problems 2 and 8 of set 1 was processing the statements underlined in problems 2 and 8 of Table 21. In problem 2 of set 1, students misinterpreted "Jenny is taller than Bobby but shorter than Sammy" to mean that Bobby, not Jenny, was shorter than Sammy. In problem 8 of set 1, students also misinterpreted "Francine finished before Susan but after Eileen". In both problems, this mistake occurred 16 out of 42 (38%) in the English version, and 19 out of 55 (35%) in the Arabic version. The occurrence of this mistake in both language versions reflects the complexity of comprehending two comparisons in the same sentence regardless of what language is being used.

- One of the mathematics teachers who conducted the set 1 to the students conveyed to me that some of the students were not familiar with the name Wadi (the Arabic name used for Sammy) which in some cases resulted in not answering the problem. I chose this name because it was popular among the students I worked with at my regular school. This name was popular among Palestinian students, but not known to students from the Arabian Peninsula. This was a great revelation to me.

Logical reasoning: problem 7 of set 2

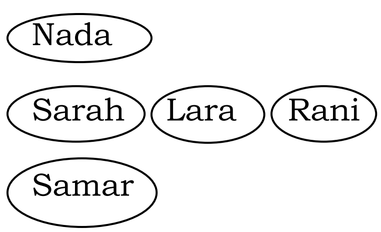
- When comparing the percentage of students who received either a '0' or '1', Problem 7 of set 2 proved to be the most difficult of the four "logical reasoning" problems – more so in the Arabic version than the English. A source of difficulty and confusion in this problem was the use of positional terms "right" and "left". Of those students who attempted to solve this problem: 22 out of 38 (59%) students in the English version and 11 out of 41 (27%) students in the Arabic version made a mistake in interpreting this particular sentence, "The apple trees are to the right of the cherry trees, and the plum trees are to the left."
- An error that was exclusive to the Arabic version, was that students who attempted to solve this problem by totally ignoring the pear trees in their solution. Of the students who incorrectly solved this problem in the Arabic version, 20 out of 41 (49%) presented apples, cherry and plum trees in their answer with no mention or reference to the pear trees, compared to only 4

out of 38 (11%) of the students in the English version. I found out from my contact in the school administration that the pear in particular had a different name in the spoken Arabic dialect for those who are originally from the Arabian Peninsula, and unless one is literate in the formal written Arabic language, the students might not be familiar with the formal label. The result was that some of them chose to ignore the statement: "The apple trees are the closest trees to the pear trees." The exact wording of the Arabic sentence was: "The closest trees to the pear are the apple". So the wording did not explicitly clarify that pear was a type of fruit trees, as was evident in the English version. One student in the Arabic version even mistakenly included Mazen, which is the Arabic name used for Michael, to be another type of the fruit trees and placed him between the cherry and the plum trees.

Logical reasoning: problem 1 of set 2:

- The success rate in solving problem 1 of set 2 was almost double (62:33) for the English version compared to the Arabic. For the Arabic version, the failure rate was almost five fold (41:8). A reason for this might be that "*saff*", the Arabic word for "line", also means "a classroom". So, the image of having a vertical line may not have been clear to some of the students. In particular, the sentence: "Lara stood between Sarah and Ron" took on a horizontal arrangement, rather than a vertical one. In fact 6 out of 28 (21%) students who have attempted to solve this problem in Arabic conveyed some kind of horizontal placement of the students waiting for the bus. Out of the six, one student used the word “beside” and two used “to the right of” to describe the position of Samar (Samantha) compared to Rani (Ron). The other two students placed the five students in the problem at three different levels. They made it a point to place Sarah directly behind Nada (Nicole) because of the statement: “Sarah stood behind Nicole”. The following diagram illustrate the solution of these two students:

(FRONT)



The last student described Samar’s position as “behind Lara, Sara, and Rani”, which again indicates placing these three at a certain level and then putting Samar behind them.

- Another source of confusion which was expressed in both language versions is that Samantha was not explicitly mentioned in the body of the word problem and the first time students knew of her existence was when the question “Where does Samantha stand in line?” was asked. In the English version, one student writes “They don’t mention Samantha at all. So I think this is a trick question.” Another writes: “There’s no Samantha in the line. Why would you write that? It doesn’t make sense. Sorry”. And another writes: “Not enough information.” In the Arabic version, roughly translating the remarks, one student writes: “There is a typo. The name Samar (the

Arabic name used for Samantha) is not found". Another writes: "Samar is not present" and a third complains about "not enough information". Interesting to note that all of the students who complained, with the exception of one, were able to successfully place the first four students in the right order.

Discussion of Category 2 Problems: "X Times as Many"

Table 22 Total Percentage of Students Who Received Either a Score of 0/1 (Failure), or 3/4 (Success) on Each Word Problem in the "Twice/Three/ Four Times As" Category Based on the Results from Table 19.

	SET 1 (%)					SET 2 (%)				
CATEGORY	Word Prob.	ENGLISH		ARABIC		Word Prob.	ENGLISH		ARABIC	
		0,1	3,4	0,1	3,4		0,1	3,4	0,1	3,4
2. "twice as"	**1**	13	85	51	42	**2**	20	72	62	28
2. "four/three times	**9**	68	29	73	22	**6**	37	57	63	29

As seen from Table 22, the majority of students (85% and 72%, respectively) solved these exercises successfully in the English version, but only 42% and 28% did so in the Arabic version. The majority of students were unsuccessful in solving problem 9 of set 1 in either languages: English (68%); Arabic (73%). As for problem 6 of set 2, the success rate for students who solved it in English was double those who solved it in Arabic (57% to 29%). Similarly, the failure rate for students who solved problem 6 of set 2 in Arabic was almost double those who solved it in English (63% to 37%).

Table 23 shows the two word problems that fall under "X Times as Many" category from each set.

Table 23 "X Times as Many" Word Problems

Category 2: "Twice" or "Three/Four Times" as Many	
Set 1	**Set 2**
1. The Browns drove a total of 140 mi on Monday. They drove twice as far on Tuesday as they did on Monday. How many miles did they drive on both days?	**2.** Freddie collected 45 stamps in the month of April, and twice as many in May. How many stamps in all did he collect in both months?
9. There were 412 men on a train. There were four times as many men as women. How many women were on the train?	**6.** A large car consumes 3 times the amount of gas a small car does per year. Mr. Smith used up 2700 Liters of gas by driving the large car. How much gas would he have used by driving the small car instead?

Characteristics of Students' Processing of problems:

Twice as many: problem 1 of set 1 and problem 2 of set 2

- Problem 1 of set 1 and problem 2 of set 2 are almost a replica of each other. For problem 1 of set 1, students presented either 140+140=280 or 140×2=280 as the solution. For problem 2 of set 2, students presented the partial solution of either 45+45=90 or 45×2=90. It appears that a common mistake was for students to neglect answering the questions for finding the total amount for both days/months. This mistake occurred in 47 out of 67 (70%) of students' solution in the English version and 40 out of 94 (43%) of students' solution in the Arabic version. Still, the gap between the success rate of students who solved either of these exercises in the English version than the Arabic version exceeds 40%.

- Interestingly, in the English version only, 3 out of 13 (23%) students who attempted to solve problem 2 of set 2 added 2 to 45 to get the "twice", instead of multiplying by 2. The same mistake did not occur in any of students' solution of problem 1 of set 1. Even though these were not ESL students, they might not have been as proficient in English and were influenced by the similarity of the word "twice" to the number "two", hence, thinking that adding two took care of "twice".
- On the other hand, in the Arabic version only, some students interpreted "twice" to mean dividing by two instead of multiply by two. This mistake was made by 6 out of the 29 (21%) students who received a '1' on problem 1 of set 1, and 2 out of the 34 (6%) students who received a '1' on problem 2 of set 2. The term "twice" in Arabic is "de'f" which is similar to the Arabic word "da'eef" which means, weak. Students who are not proficient in the Arabic language might mistakenly assumed that they need to divide by 2 to get a smaller number. Then again, it might be a conceptual mistake of interpreting which number is twice the other.

Four/three times as many: problem 9 of set 1 and problem 6 of set 2

- As indicated by Table 22, the majority of the students were unsuccessful in solving either language version of problem 9 of set 1. Students performed better on problem 6 of set 2 than they did on problem 9 of set 1 in both languages. In the English version, the success rate improved from 29% in problem 9 of set 1 to 57% in problem 6 of set 2. In the Arabic version, the success rate improved slightly from 22% in problem9 of set1 to 29% in problem6 of set 2. One would think that the wording of this particular problem would help students figure out that the large car would naturally consume more than the small car and hence they need to divide to get a smaller number for the smaller car. It seemed this factor had more positive impact on students' performance in the English version than the Arabic version.
- A common mistake in both problems is that students multiplied by 4 instead of divided by 4 to figure out the number of women on the train in problem 9 of set 1, and multiplied by 3 instead of divided by 3 to figure out how much gas was used by the small car in problem 6 of set 2. What is interesting is that this mistake was more common in the English version than in the Arabic version. 43 out of 70 (61%) of the students who attempted to solve the English version made this mistake; where as, only 22 out of 82 (27%) of the students who attempted to solve the Arabic version made the same mistake. This is expected since the wording in the Arabic language is less ambiguous than the English language. For example, "there

were four times as many men as women" is stated in Arabic literally as: "the number of men was four times the number of women". There was no way to express this sentence in the Arabic language at the same level of difficulty as in the English language.

- There was some evidence of guessing or confusion in the students' solution where they either added or subtracted the 4 in problem 9 of set 1 or the 3 in problem 6 of set 2 to find the answer. and problem 6 of set 2. This mistake was made by 8 out of 70 (11%) students in the English version and 23 out of 82 (28%) students in the Arabic version of both problems.
- One student solving the English version of problem 6 of set 2 complained that: "we don't know how gas works. What are liters, anyway?" , and left the problem without solving it.

Discussion of Category 3 Problems: "Fewer Than"

Table 24 Total Percentage of Students Who Received Either a Score Of 0/1 (Failure), or 3/4 (Success) on Each Word Problem in the "Fewer Than" Category Based on the Results from Table 19.

	SET 1 (%)					SET 2 (%)				
CATEGORY	Word Prob.	ENGLISH		ARABIC		Word Prob.	ENGLISH		ARABIC	
		0,1	3,4	0,1	3,4		0,1	3,4	0,1	3,4
3. "fewer than"	**5**	25	67	47	40	**5**	31	63	48	44
3. "fewer than"	**10**	33	66	87	12	**9**	26	60	70	18

Students performed similarly on problem 5 of set 1 and problem. 5 of set 2. The success rate of English to Arabic in both exercises was roughly 65:40. The failure rate was also similar from set 1 to set 2 for each language version: the English was 25% to 31% and the Arabic was 47% to 48%. As for problem 10 of set 1 and problem 9 of set 2, the gap between students' performance in the English version and the Arabic version was 54% and 42%, respectively. The success rate of English to Arabic in problem 10 of set 1 was 66:12 and in problem 9 of set 2 was 60:18. On the other hand the failure rate of English to Arabic in problem 10 of set 1 was 33:87 and in problem 9 of set 2 was 26:70. The verwhelming majority of students (82%) who did the Arabic version of these two exercises were unsuccessful while less than 33% failed the English version.

Table 25 shows the two word problems that fall under "fewer than" category from each set.

Table 25 "Fewer Than" Word Problems

Category 3: "Fewer Than"	
Set 1	**Set 2**
5. At basketball practice, Justin scored 36 points. Brad scored 41 points. Kevin scored 10 fewer points than Justin and Brad combined. How many points did Kevin score?	**5.** There were 46 women and 35 men attending a wedding. The number of children attending the same wedding was 15 fewer than the number of men and women combined. How many children were attending this wedding?

Table 25 (Continued)

CATEGORY 3: "FEWER THAN"	
SET 1	**SET 2**
10. Lisa has 11 quarters. She has twice as many dimes as quarters, and 5 fewer nickels than dimes. She has the same number of pennies as the other coins combined. How many of each coin does Lisa have?	**9.** Mary has 15 white marbles. She has twice as many blue marbles as white marbles, and 7 fewer red marbles than blue marbles. How many red marbles does she have?

Characteristics of Students' Processing of problems:

Fewer than: problem 5 of set 1 and problem 5 of set 2

- The first common mistake that appeared in both problem 5 of set 1 and problem 5 of set 2 was misinterpreting the "fewer" concept. After correctly finding the combined number of points/adults, the student added instead of subtracted to find the final answer. This mistake was made by 11 out of 41 (27%) students in the English version and 16 out of 62 (26%) students in the Arabic version.
- The second type of mistake common to both problem 5 of set 1 and problem 5 of set 2 was not processing the idea of "combined". In problem 5 of set 1, students subtracted 10 from either Justin's or Kevin's score withouth adding their scores first. In problem 5 of set 2, students subtracted 15 from either the number of men or women without first adding them up. This

mistake was made by 6 out of 41 (15%) students in the English version and 5 out of 62 (8%) students in the Arabic version.

- The third type of mistake common to both problem 5 of set 1 and problem 5 of set 2 was to take away 10 from the points scored by each of Justin and Kevin or to take 15 fewer from the number of each group of men and women, and then adding the two differences up. This mistake was made by only 1 student in the English version of problem 5 of set 1 and 5 out of 62 (8%) students in the Arabic version of both problems.
- The final mistake that appeared only in the Arabic version of both problems was to present the answer to problem 5 of set 1 to be 10 and the answer to problem 5 of set 2 to be 15. This mistake was made by 10 out of 62 (16%) students in both problems. This shortcoming might reflect the lack of comprehension of the student to either problem.

Fewer than: problem 10 of set 1

- The high failure rate (87%) of students solving problem 10 of set 1 might partly be explained by the language factor. Unlike English, Arabic has no special name for a quarter, dime, nickel, or penny. So to refer to the different kind of coins, words describing the value of the coin had to be used. The problem in Arabic was:

لَدَى شَيْمَاءُ 11 قِطْعَة مِنَ ال"رُبْعِ دولار". مَعَهَا مِنْ قِطعِ ال"عَشَرَةِ سَنْتَاتٍ" ضِعْفَ عَدَدِ ال"رُبْعِ دولار"، ومِنْ قِطعِ ال"خَمْسَةِ سَنْتَاتٍ" 5 أَقَلَّ مِنْ قِطعِ ال"عَشرَةِ سَنْتَاتٍ". مَعَهَا مِنْ قِطعِ ال"واحِدِ سَنْتٍ" نَفْس مَجْمُوع بَقِيَّة القِطعِ النَّقْدِيَّة.
كَمْ عَدَدُ كُلٍّ مِنَ القِطعِ النَّقدِيَّة مَعَ شَيْمَاء؟

The words in quotation refer to the value of the coin which translates to "quarter dollar", "ten cents", "five cents", or "one cent". Then the students needed to keep track of how many of each type they had; so they started with 11 pieces of "quarter dollar", then they had to process the idea of double that number, and so on. So, there are multi-level of complexity and a high risk for confusing the value of the coin with the number of pieces of each coin. In fact, half of the 87% of students who failed to solve this problem did not attempt to solve the problem and received a 0 on the rubric. This partly reflects that students were not able to move beyond reading the word problem.

- 9 out of the 39 (23%) who attempted to solve the problem in Arabic just added or subtracted the two numerals found in the problem, namely '11' and '5', versus 6 out of 16 (38%) did the same in the English version.
- A mistake that appeared in both the English and Arabic version is students summing the total number of coins that Lisa had, even though the question asked "how many of each coin does Lisa have?". This minor mistake was made by 3 out of 48 (6%) of the students who attempted to solve the problem in the Arabic version, and 6 out of 26 (23%) in the English version.
- 13 out of 48 (27%) students who attempted to solve the Arabic version and 5 out of 26 (19%) of the English version confused the amount of money with the number of coins in some part of their solution. For example, one student solving the English version presented his/her answer to be:11 quarters, 220 dimes (value of 22 dimes), 85 nickels (value of 17 nickels), and 316 pennies (which he got from adding 11+220+85+316). One student

solving the English version and another solving the Arabic version, presented the number of coins correctly for quarters, dimes and nickels, but when it came to the pennies, they evaluated the amount of money they had: 275 (=11 quarters)+220 (=22 dimes)+85(=17 nickels) = 580 pennies. Another student solving the Arabic version figured the value of 11 quarters ($2.75), then doubled that amount (5.50 dimes), took away 5 nickels (5.25 nickles), added all up to get 13.50 for the pennies, and finally doubled that to present the total amount of money: $27.00. This student made no distinction between the number of coins versus their value.

Fewer than: problem 9 of set 2

- The high failure rate (70%) of students solving problem 9 of set 2 in the Arabic version might also be partly explained by the language factor. Different people from different Arabic cultures/regions refer to marble by a different name. Hence, even though this problem seems to be simpler than problem 10 of set 1, the lack of knowledge of what is meant by كِلَّةٍ (singular form of marble) and الكِلل (plural form of marble) may have contributed to the high failure rate.
- A common mistake found in the Arabic version was processing "fewer" but not "twice". 13 out of 41 (32%) students presented 15-8=7 as their solution in the Arabic version, whereas only 1 out of 22 (5%) made the same mistake in the English version.

- One student in the English version once again added 2 to 15 to get the "twice", instead of multiplyed it by 2. This student presented the solution as: 15 white, 17 blue, 10 red.
- One student in the Arabic version once again interpreted "twice" to mean dividing by 2 instead of multiplying by two. This student presented the solution as: 15 white, 7.5 blue, .5 red. The fact that 7.5 seemed a reasonable number for marbles confirms that this particular student is unfamiliar with the literal meaning of كِلَةٍ.

Discussion of Category 4 Problems: "Think Backwards"

Table 26 Total Percentage of Students Who Received Either a Score Of 0/1 (Failure), or 3/4 (Success) on Each Word Problem in the "Think Backwards" Category Based on the Results from Table 19.

	SET 1 (%)					SET 2 (%)				
CATEGORY	Word Prob.	ENGLISH		ARABIC		Word Prob.	ENGLISH		ARABIC	
		0,1	3,4	0,1	3,4		0,1	3,4	0,1	3,4
4. "think backwards"	7	54	42	72	17	3	64	30	76	14
4. "think backwards"	4	20	74	41	53	8	19	77	48	49

Problem 7 of set 1 and problem 3 of set 2 are very similar in structure and content. These two problems seemed to had been more challenging for students in general, but especially for those solving the Arabic version. This is reflected in the very low success rate of students solving these problems in the Arabic version (17% and 14% respectively). The success rate of students solving the English version of these problems are almost double (42% and 30%, respectively), but still below 50%. Likewise, problem 4 of set 1 and problem 8 of set 2 are very similar in structure and content. In both of these problems, the rate of success of the English version to the Arabic version is almost identical for problem 4 of set 1 (74:53) and problem 8 of set 2 (77:49). Also, within the Arabic version, the rate of students who received a '3' or '4' to those who received a '0' or '1' was similar in each problem (53:41 and 49:48, respectively). Among the problems in the Arabic version, the success rate was the highest for problem 4 of set 1 and problem 8 of set 2.

Table 27 shows the two word problems that fall under "think backwards" category from each set.

Table 27 "Think Backwards" Word Problems

CATEGORY 4: "THINK BACKWARDS"	
SET 1	**SET 2**
7. John thought of a number, then subtracted 35 from it, then multiplied the difference by 3, then added 60 to the product, and got 180. What was the number John thought of?	**3.** Omar thought of a number, he then subtracted 25 from it, multiplied the difference by 5, added 50 to the product and got 225. What was the number Omar thought of?

Table 27 (Continued)

CATEGORY 4: "THINK BACKWARDS"	
SET 1	**SET 2**
4. Charity spent \$3.26 for book covers, \$12.42 for a short story book, and \$2.65 for glue. She returned home with \$8.23. How much money did she have before going shopping?	**8.** Mira spent \$15.60 for books, and \$9.38 for pencils and \$3.12 for sweets. She returned home with \$6.50. How much money did Mira have before going shopping?

Characteristics of Students' Processing of problems:

*Think backwards: problem 7 of set 1 and problem 3 of set 2***:**

- "It is too confusing" and "not at our level" was a couple of remarks given by students from the English version about the difficulty level of both problems, which might explain the high level of failure in these problems.
- A common mistake appearing in both language versions was to arbitrarily add and/or subtract some or all the numbers mentioned in the problem. This mistake was made by 9 out of 74 (12%) students in the English version and 21 out of 107 (20%) students in the Arabic version.
- Some mistakes are worth mentioning but without the percentages since they appeared in 4 or less individual solutions in either language version. One was to run the series of operations in the problem on the last number mentioned in the problem: "180-35×3±60" for problem 7 of set 1, and "225-

25×5+50” in problem 3 of set 2. Another was to run the series of operations on the first number mentioned in the problem: “35×3+60” for problem 7 of set 1, and “25×5+50” in problem 3 of set 2. Another was to calculate the operations out of order or to flip flop between correctly reversing the operation or incorrectly running the exact operation mentioned in the problem.

- A particular mistake that appeared in only 3 out of 53 (6%) in the Arabic version of problem 7 of set 1, was to interpret “subtracted 35 from it” to mean division.

Think backwards: problem 4 of set 1 and problem 8 of set 2

- As indicated in Table 26, the success rate was high for both problems in the English and Arabic versions. What was interesting is that patterns in student solutions emerged in both versions.
  1. Students added the three things purchased along with the amount of money Charity/Mira had before she went shopping in the same step. It seems as if no conceptual distinction was made between the money spent and the money left. This method was used by 59 out of 117 (50%) students in the English version and 59 out of 95 (62%) students in the Arabic version.
  2. Students added the three things purchased first, then added to the sum the amount of money Charity/Mira had before she went shopping. It seems as if some kind of conceptual distinction was made between the

money spent and the money left. This method was used by 44 out of 117 (38%) students in the English version and 21 out of 95 (22%) students in the Arabic version.

3. Students added each item separately. This method was used by 12 out of 117 (10%) students in the English version and 11 out of 95 (12%) students in the Arabic version.

- The most common mistake in both problems was to not add the money left with Charity/Lisa to the total amount of money spent to figure out how much she had before going shopping. This mistake was made by 17 out of 28 (61%) students in the English version and 10 out of 47 (21%) students in the Arabic version.
- For problem 4 of set 1, one student solving the English version added only the value of the three things purchased, got $18.33, and decided that Charity must have had $20.00. For that student, it seemed that it was more probable to have a $20.00 bill than to have the exact amount of $18.33. Even though the answer was incorrect, however the student's thinking of the realistic or practical implication of the answer is very interesting.

Discussion of Category 5 Problems: "Multi-step Problem"

Table 28 Total Percentage of Students Who Received Either a Score Of 0/1 (Failure), or 3/4 (Success) on Each Word Problem in the "Multi-Step Problem" Category Based on the Results from Table 19.

	SET 1 (%)					SET 2 (%)				
CATEGORY	**Word Prob.**	**ENGLISH**		**ARABIC**		**Word Prob.**	**ENGLISH**		**ARABIC**	
		0,1	**3,4**	**0,1**	**3,4**		**0,1**	**3,4**	**0,1**	**3,4**
5. Multi-step problem	**3**	60	39	73	22	**4**	49	18	77	5
5. Multi-step problem	**6**	64	36	87	11	**10**	77	20	87	10

The success rate of students solving problems 3 and 6 of set 1 and problems 4 and 10 of set 2 was among the lowest in the English and the Arahic versions. This shows, as expected, that this type of problems seems to be most challenging and difficult to students, regardless of the language. Still, the success rate of students solving the English version to those solving the Arabic version is almost double for problem 3 of set 1 (39:22) and problem 10 of set 2 (20:10), and more than triple for problem 6 of set 1 (36:11) and problem 4 of set 2 (18:5). The percent of students who received a '0' or '1' on these four problems ranges from 49% to 77% in the English version and 73% to 87% in the Arabic version.

Table 29 shows the two word problems that fall under the "multi-step problem" category from each set.

Table 29 "Multi-Step Problem" Word Problems

CATEGORY 5: MULTI-STEP PROBLEM	
SET 1	**SET 2**
3. Mr. Michael earns $6 for each hour of work, and double that for each additional hour that exceeds 40 hours per week. He worked a total of 42 hours. Mr. Smith earns $8 for each hour of work. He worked for 35 hours. Who will get paid more? By how much?	**4.** Mr. John wants to rent a car to go on a trip. The cost is $35 per day as long as the mileage does not exceed 100 km, otherwise he has to pay $5 for each extra km. Another option is to pay $60 for each day. Which option is the best, if the trip is going to last 3 days and the total distance will be 150 km?
6. Mrs. Price's long distance phone calls usually last an average of 18 minutes. The long distance company offered her two plans: Plan A: the first three minutes cost $2.25 and $0.30 for each additional minute; Plan B: flat rate of $0.50 per minute. Which plan is cheaper? By how much?	**10.** William pays $35 a month for 400 minutes of cell phone use and $0.40 for each extra minute. His friend Andrew pays $0.20 per minute for cell phone usage. If each used a total of 500 minutes in one month, who would pay more? By how much?

Characteristics of Students' Processing of problems:

Multi-step problem: problem 3 of set 1 and problem 4 of set 2

- Students did relatively better on problem 3 of set 1 than on problem 4 of set 2 in the English version (39:18) and in the Arabic version (22:5). In both language versions, most students who attempted to solve problem 3 of set 1 did not account for the 2 hours overtime in their solution. Their solution was: 42×6=$252 for Mr. Michael, and 35×8=$280 for Mr. Smith. The few students who attempted to solve problem 4 of set 2 also did not account for the 50 km extra driven. Their solution was: 3×35=$105 for first option, and 3×60=180 for the second option. This oversight was made by 20 out of 89 (22%) students in the English version, and 25 out of 111 (23%) students in the Arabic version for both problems. Only 14 out of 89 (16%) students in the English version and 7 out of 111 (6%) students in the Arabic version accounted for the 2 hours overtime in problem 3 of set 1 and for the extra 50 km in problem 4 of set 2 in their solution of either problem.
- For problem 3 of set 1, some students totally ignored the 2 hours overtime and presented their solution for Mr. Michael to be: 40×6=$240, and for Mr. Smith to be as above: 35×8=$280. This mistake was made by 7 out of 53 (13%) students in the English version and 8 out of 67 (12%) students in the Arabic version.
- For problem 4 of set 2, some students chose to multiply $5, the fee for each km beyond the 100km limit, by the total distance driven, 150. This

mistake was made by 3 out of 36 (8%) students in the English version, and 3 out of 44 (7%) students in the Arabic version.

- For problem 4 of set 2, the only part of the problem that some students were able to solve correctly was to calculate the cost of the second option: $3 \times 60 = 180$. This was done by 7 out of 36 (19%) students in the English version and 4 out of 44 (9%) students in the Arabic version.
- For problem 4 of set 2, three students in the English version decided on which option was best through personal preference and not through any mathematical calculation. Two students chose the $60 per day option because “it will be easier to pay” and “it is not complicated”. The third student also picked the $60 per day option because “you don’t pay for extra km”.

Multi-step problem: problem 6 of set 1 and problem 10 of set 2

- A common mistake to both problems was students evaluating the additional 15 minutes without adding the cost of the first three minutes ($2.25) for problem 6 of set 1, and students evaluating the cost of the minutes that exceed the 400 minutes limit without adding the monthly charge ($35) for problem 10 of set 2. This mistake was made by 9 out of 120 (8%) students in the English version and 4 out of 107 (4%) students in the Arabic version.
- More students were able to only solve the second part of both problems due to lack of complexity. These students were able to correctly calculate the cost of plan B for problem 6 of set 1 ($0.50×18=$9.00) and the amount of

money Andrew pays for his cell phone usage ($0.20×500=$100). A total of 20 out of 120 (17%) students in the English version and 13 out of 107 (12%) students in the Arabic version solved the second part of either problem.

- For problem 6 of set 1, some students misinterpreted “the first three minutes cost $2.25” to mean that $2.25 for each of the first three minutes, and hence multiplied $2.25 by 3 to get the cost of the first three minutes. This mistake was made by 14 out of 64 (22%) students in the English version and 6 out of 60 (10%) students in the Arabic version.

General Remarks About Students’ Processing of the Problems:

- Some students solving the Arabic version wrote a translation of some terms or sections of the problems in English.
- A student given the Arabic version complained that “this Arabic writing is not the same type of Arabic we learn in our school”. If I understand this statement properly, it seems that the student reads Arabic in a literature setting rather than a technical setting for mathematical word problems.
- Some students wrote their answers in the Arabic version using English sentences. Some students tried awkwardly to put their answers using the Arabic wording. Others used well written Arabic statements that reflected their proficiency in the Arabic language.
- Some students tried to use the Arabic numerals to present their answer, but ended up writing the number in the reverse direction. For example, if the answer is 45, the student wrote (٥٤) which is equivalent to 54.

Summary of Qualitative Results

Some common differences and similarities in the problem solving processes of Arab-American students became apparent within the two language versions. Mistakes in deciphering statements with double comparison occurred in similar frequencies in both language versions. Students complained about hidden information within a logical word problem in both language versions. Students' failure to answer all parts of the problem appeared in several problems in both language versions. Students had the lowest success rate for multi-step problems regardless of the language version. On the other hand, the students had the highest success rate for solving one of the two "think backwards" problems in both sets 1 and 2, where they had to figure how much money did Charity/Mira have before going shopping. Students solving the Arabic version struggled with the other "think backwards" problem within both sets 1 and 2, more evidently than their English counterparts. One mistake that appeared less frequently in the Arabic version than in the English version was interpreting "four times as many". Closer analysis showed that expressing this relationship in Arabic proved to be less ambiguous than in English, where the wording matched the mathematical interpretation. The problem of figuring the number of each type of coin proved to be problematic for students solving the Arabic version, since there was no special label to refer to each type of coin as there is in English. Difficult vocabulary in both language versions contributed to some student mistakes. Students made mistakes interpreting mathematical words such as "fewer" and "twice" in both language versions. Other vocabulary words that proved to be problematic to students solving the Arabic version were the name "Wadi", the "pear" fruit, and the Arabic word for "marble" and "line".

Conclusion

Both quantitative and qualitative aspects of this research provided a global understanding of Arab-American students' performance on word problems in both languages and the specific areas for support needed, respectively.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study investigated the effect of the language of the problem on the performance of students who are bilingual in English and Arabic. This study aimed to address the lack of research available on the Arab-American student population. This study adds to the existing body of research on bilinguals through its attention to Arab-American students. This study used qualitative and quantitative measures to assess their problem solving ability in both languages. In addition, this study used SAT reading comprehension and Arabic final average as quantitative measures of students' comprehension level in either language that were not stressed in other studies.

Purpose of the Study

The purpose of this study is to investigate the performance of Arab-American students when solving mathematical word problems presented in their home language (Arabic) or in their language of instruction (English). This study also investigated the effect of students' comprehension levels in the Arabic and English languages on their mathematical problem solving abilities.

Research Questions and Findings

This study aimed to answer the following research questions:

1. Does the language in which a mathematical word problem is stated have an effect on the performance of the bilingual students? Specifically, is there a difference in the performance of Arab-American students when solving word problems in English compared to solving word problems in Arabic? Null Hypothesis: There will be no significant difference in the performance of Arab-American students when solving word problems in English compared to solving word problems in Arabic.
2. Do Arab-American students with higher levels of Arabic proficiency perform better in either or both versions of the word problems? Null Hypothesis: Arab-American students with higher levels of Arabic proficiency will not perform better on the Arabic version of the word problems than on the English version.
3. What are some common differences and similarities in the problem solving processes of Arab-American students as they solve problems in English or Arabic?

There were three covariates: SAT reading comprehension, SAT mathematics problem solving, and Arabic final average. The results from the quantitative analysis showed that SAT mathematics problem solving and Arabic final average were the only two covariates significant in explaining variance in student performance on set 1 and set 2. The results from different statistical analysis confirmed that Arab-American students performed significantly better on the English version of both set 1 and set 2 than on the

Arabic version. Moreover, Arabic final average was a significant predictor of student performance on the Arabic version of set 1 and set 2, while SAT reading comprehension was a significant predictor of student performance on the English version of set 1 and set 2. SAT mathematics problem solving was a significant predictor of student performance on all except for the Arabic version of set 1.

Some common differences and similarities in the problem solving processes of Arab-American students became apparent within the two language versions. Students had difficulties with deciphering statements with double comparisons, dealing with hidden information within a word problem, answering all parts of the problem, and working out multi-step problems regardless of the language version. Students did better on deciphering "four times as many" in the Arabic version than in the English version. Closer analysis showed that expressing this relationship in Arabic proved to be less ambiguous than in English, where the wording matched the mathematical interpretation.

Difficult vocabulary contributed to some student mistakes in both language versions. Students made mistakes interpreting mathematical words such as "fewer" and "twice" in both language versions. Other vocabulary words that proved to be problematic to students solving the Arabic version were the name "Wadi", the "pear" fruit, and the Arabic word for "marble" and "line".

Comparison to Other Studies

The results of this study supports the findings reported in Aiken (1972) where the partial correlation between reading comprehension and problem solving abilities was found to be higher for both English speaking fourth and eighth graders than the partial correlation between computational ability and problem solving ability, with the third factor partialed out in both correlations. In this study, for groups taking the English version of the test, SAT reading comprehension was moderately to highly correlated with student performance. Moreover, SAT reading and mathematics were found to be highly correlated, which means that the better a student is in reading comprehension, the better he/she will perform on mathematics problem solving. On the other hand, it makes sense that Arabic final average had a low correlation with either SAT reading comprehension or SAT mathematics problem solving, because students who perform well in the Arabic subject need not necessarily perform well on either reading comprehension or problem solving.

This study found that Arab-American students performed significantly better on the English version of the word problems than on the Arabic version. Bernardo (2005) found that Filipino-English bilingual students tend to understand word problems better in their more proficient language, hence, this study may imply that the Arab-American students studying in the United States were more proficient in the English language, which happens to be the language of instruction. Unlike Bernardo (2005) and Adetula (1990), Arab-American students did not perform better when problems were presented in their mother tongue. An explanation may be that unlike my study, their student population resided in their home country where they had sufficient support and reinforcement to be proficient in their mother tongue. In this study, exposure to Arabic for Arab-American students was guaranteed only through taking Arabic classes, which is usually once a day and some home interaction which was usually conducted in the spoken, not the formal Arabic.

Several studies found a strong correlation between the level of students' linguistic abilities and mathematics achievement (Adetula, 1990; Bernardo, 2002; Dawe, 1983; Cocking & Chipman, 1988; Earp & Tanner, 1980; MacGregor & Price, 1999), and between reading comprehension and problem solving (Mestre, 1988; Aiken, 1972; Knight & Hargis, 1977; Bernardo, 1999). Knight and Hargis (1977) found that the source of difficulty for solving mathematics word problems was sometimes comprehending the problem rather than manipulating the numbers. Moreover, Morales, Shute and Pellegrino (1985) found that the main contributor to errors in student solutions was selection of inappropriate procedure rather than computational deficiencies. My study supports these studies in that being proficient in the language in which a word problem is written had a positive effect on students' performance. SAT reading comprehension was a significant predictor of students' performance on the English version of the word problems, whereas Arabic final average was a significant predictor of students' performance on the Arabic version of the word problems.

According to Duran (1985), limited ability in the English language was a major contributor to difficulties faced by students from non-English backgrounds; however, it is not the only factor affecting their academic functioning. In support of this, my study found that mathematics problem solving abilities was a significant factor in explaining differences in students' performance on both language versions of the word problems. In fact, SAT mathematics problem solving was the most influential variable in predicting student performance on the word problems, followed by the Arabic final average.

Aiken (1972) points out that mathematics itself is a "specialized language" and Adetula (1990) accentuates the fact that word problems denote "a language within a language". In support of this fact, a student in my study wrote: "this Arabic writing is not the same type of Arabic we learn in our school." The student's remark corroborates what is expressed by Aiken (1972) and Adetula (1990). Comprehending the Arabic within a mathematical word problem setting proved to be more challenging than learning Arabic in a literary context.

A source of difficulty is what sociolinguists identify as the linguistic distance in reference to the language differences in their semantics, or in references to their function and status (Dawe, 1983). Unlike European languages such as French and Spanish which share a common origin with the English, the distance between English and Arabic is wide. Duran (1985, 1988) reports on the challenges and advantages faced by the language learners as predetermined by the similarities and differences between the two language systems. One main difference is that Arabic utilizes totally different alphabet and numerals from English. Another main difference is that English is written left to right, where as Arabic is written right to left. The direction alone poses a source of difficulty for students as was shown in one aspect by switching the order of writing the number 45 in Arabic as '54'.

Many studies (Dawe, 1983; De Avila & Duncan, 1985; Bernardo, 2002) reported that students' difficulties and poor performance in problem solving are more of a linguistic nature rather than intellectual or cognitive. Aiken (1972) distinctively identified difficult vocabulary and syntax as impediments to successful problem solving. Findings by this study with respect to analyzing students' solutions assert Aiken's contention. Words that proved to be problematic for some students in both the English and the Arabic versions were 'twice' and 'fewer'. Spanos and his colleagues (1988) pointed out that some students who are not keen on the English language might find synonymous words or phrases that describe the same mathematical operations to be problematic. For example, students might be more comfortable thinking of 'double' than 'twice', or of 'less' than 'fewer'. Moreover, students might be totally unfamiliar with that particular word in one of the two languages. However, difficult vocabulary contributed to student errors, especially in the Arabic version. 'Pear' and 'marble' were unfamiliar words for some students that might have contributed to their faulty or lack of solutions. "Saff", the Arabic word for line, could also mean "a classroom" was ambiguous for some students to understand. Another word that proved to be problematic to some students is the Arabic name Wadi. Even though it is popular practice by educators and text book authors to insert special names for making a problem culturally sensitive, this study showed that this may not be an easy task. Indeed, even though the researcher is fluent in both languages, carefully constructed the test to be analogous and culturally sensitive in both languages, students still had a problem with some of the vocabulary. Names vary in different segments of a given culture and that fact may be problematic for some students in the sample. This study showed that it is important for a child that all key parts of the problem are clear before venturing to solve the problem.

Research (Mestre, 1988) reports that students have difficulty distinguishing between variables and labels in problems resembling what has come to be known as the student-professor problem: "There are 6 times as many students as professors at this university. Write an equation to express this relation." The difficulty of the problem lies with mapping mathematics symbols to the word-order. Students in the present study made this mistake when solving the problem "there were four times as many men as women" in the English version; however, the mistake occurred less frequently in the Arabic version. When stating the same statement in the Arabic language, there was higher clarity in that language that facilitated better selection of the mathematical operation demanded by the word problem.

Regardless of the language used, students made some mistake in deciphering statements that involved double comparisons. Students were intimidated when some information was hidden within the problem, as with problem 1 in set 2 where Samantha's name was not revealed until the end of the problem. In some cases, students failed to answer all parts of the problem. For problem 1 in set 1 and problem 2 in set 2, the students calculated the 'double' but not the total miles driven on both days, or the total stamps collected in both months. Moreover, students found multi-step problems in which they had to compare between two phone call plans or two payment options to be challenging regardless of the language.

Implication for Teaching

This study recommends the following for enhancing Arab-American students' problem solving achievement:

1. In general, there need be little concern that mathematics tests given in English may penalize the performance of Arab-American students who speak Arabic at home. However, teachers need to be sensitive to those students who are more fluent in the Arabic language than the English language.
2. Use both English and Arabic to clarify problem statement and any ambiguity.
3. Allow students to use the language they prefer to express the problem solving process. The aim is to use both languages to support each other in achieving conceptual understanding, and not have one language take the place of the other.

4. Provide more experiences with multi-step problems and with problems that require solving backwards.
5. Provide more experience with mathematics vocabulary where an operation can be expressed in different ways, e.g. ‘double’ vs. ‘twice’.
6. Unless using names of students from a given class, verify that the names inserted for making a problem on an exam culturally relevant is a common name in that culture. Just because students may speak the same language does not imply that students may share similar cultural practices and/or dialect. This is an example of the difficulty that ESL students have when taking tests in the language they are not familiar with.
7. Have students pay particular attention to answering the question by rereading the problem.

Implication for Further Study

1. This study should be replicated with a greater number of students to increase reliability and validity.
2. The difficulty level of this study’s verbal problems was higher than that of Bernardo (2005) and Adetula (1990). It may well be that the results of a similar study using the same difficulty level as Bernardo (2005) and Adetula (1990) might produce similar results.
3. A test on Arabic that more closely measures students’ Arabic comprehension level would strengthen the results of this study.

4. This study examined students written responses to analyze their thinking process. Future studies should have student interviewed or think aloud to enhance the validity of the interpretation of the written work.
5. Since the reliability of the word problem sets has been established, future studies may limit the student population to ESL (English as a Second Language) and ASL (Arabic as a Second Language), and then compare their problem solving abilities on both language versions.
6. Reproduce this study with Arab-American students who are proficient in both languages and compare their problem solving abilities with those of monolingual students.
7. Future studies should consider comparing the mathematics performance of Arab-American girls to Arab-American boys in solving word problems in both languages.
8. The survey in Appendix G was created but not used in this study, because the school forgot to distribute it. Further studies might include it to research the correlation between the preferred language as identified by the students, and their performance on the mathematics word problems on either language.
9. Replicate the Arab-American study for students in their native country. Results might turn out to be similar to those of Bernardo (2005) and Adetula (1990).

Conclusion

No research on Arab-American abilities in solving mathematics word problems was found. The lack of research on this particular student population is disturbing and needs to be addressed. This study shows that more research is needed to investigate ways to better prepare such students in mathematics. As with many studies, the results will very likely provide useful information for the general population students' understanding in mathematics.

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Appendix A: Principal Survey

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Subject: LETTER OF INTRODUCTION & PRINCIPAL SURVEY

Assalamu Alaikum,

My name is Samar Sarmini. I am a doctoral student in Math Curriculum & Instruction at the University of New Orleans, Louisiana, under the direction of Professor Yvelyne Germain-McCarthy. The topic of my doctoral dissertation is studying the effects of language on the students' ability to solve math word problems. My study focuses on bilingual students who speak both English and Arabic and how their knowledge of more than one language might play a role in their ability to successfully solve mathematics word problems. I am also interested in finding out how the language that the word problem is written in affects how students process the information and their solutions.

Since 2001, as an Arab Muslim, a lot of negativity has been channeled at our community and our students. Lack of research for our particular culture is disheartening. As I research this topic, very few studies, if any, have considered the Arabic student population. Most of the available research has focused on the effect of language on minority groups' problem solving skills, mainly Hispanics. In my role as a math educator, I have chosen to focus my dissertation on Arab students in hopes that my research can fill part of the gap present in the current literature and ignite the interest of more researchers to listen to the voices of the Arabic students and be able to better address their academic needs. I also hope to provide essential information to better educate teachers in both Islamic and non-Islamic schools about the important role language plays in students' overall academic development and the need to use their culture and language background to the students' advantage.

Research Questions

1. How is the level of the student's comprehension in the first (Arabic) and second (English) languages related to performance in mathematical problem solving?
2. Does the language in which the word problem is stated have an effect on the performance of the bilingual students?

Procedures for this Research

Students in grades 5, 6, and 7 will be asked to participate in this study. Each student participant will be asked to fill a short survey. Participating students will be given two sets of 10 word problems to solve, and each set will be solved on a separate day. The participating students in grades 5, 6, and 7 will be randomly assigned to one of four groups: one group will solve both sets of word problems in English, another group will solve both sets of word problems in Arabic, and the other two groups will solve one set in English and one set in Arabic interchangeably. Collecting the student data for this study will take approximately one mathematics class period on two separate days, that may be on **Thurs., Mar. 27** and the following **Tues., Apr. 1** (if the school agrees). This will conclude the student data collection for this study.

Permission to access students' test scores

To better interpret the results of this study, your permission and the parents' permission will be asked to grant the researcher a copy of the participating student's test scores on the Stanford Exam on the **Reading** and **Math** Subjects, as well as scores on **Arabic** exams that measures **comprehension**. <u>These scores will be destroyed immediately upon the conclusion of the study</u>.

Protection of Confidentiality

All measures will be taken to protect the confidentiality of the participants. Information from the tests and the survey will be coded by the principal investigator to protect anonymity. All reports and future publications will report information in a format that will ensure concealing the identity of all participants. All data will be securely stored in the office of the principal investigator's supervisor in the Education Building at the University of New Orleans.

Attached are a copy of the **principal** support letter and the **principal** survey that will hopefully take no longer than 15-20 minutes of the principals' valuable time to fill. I am providing you with a sample form for the principal support letter. Please feel free to change/add to it. By writing the principal letter of support and returning the surveys with the filled responses, you would provide me with your solid support for this study. Your support is crucially needed at your earliest convenience. May God bless you and provide you and your school with continuous success.

PRINCIPAL LETTER OF SUPPORT

SCHOOL NAME/LETTER HEAD

Dear Mrs. Sarmini,

I have reviewed your doctoral study titled "Exploring the relationship between the level of comprehension of bilingual students' first and second languages and their competence in solving word problems in both languages" to occur at my school. I appreciate your efforts to enhance the learning of Arab American students. I will provide you with whatever support you need in terms of data, recruitment of teachers and parents from my school.

Sincerely,

Please provide the following information with the assurance that all information therein will remain confidential

1. Name of school: ___________________________
2. Name of principal: ___________________________
3. School Branch: ☐ girls ☐ boys
4. How many students are enrolled in each of the following grade levels for the current academic year?

   ⑤ ⑥ ⑦

   ____ ____ ____

5. How many sections are in each of the following grade levels?

   ⑤ ⑥ ⑦

   ____ ____ ____

6. Are there any honor classes? ○Yes ○No
7. If Yes, please bubble the grade levels that offer honor classes:

   ⑤ ⑥ ⑦

   ____ ____ ____

8. Are there any bilingual courses offered to students? ○Yes ○No
   a. If yes, please give a brief description:

      ____

      ____

9. Do students take any kind of standardized tests? ○Yes ○No
   a. If yes, please list their names and specify the grade levels these tests are administered to:

      ____ Grades: ___________

      ____ Grades: ___________

      ____ Grades: ___________

      ____ Grades: ___________

10. Kindly specify the number of students enrolled at the different levels of Arabic classes offered for each of the following grades. Also indicate whether the advanced Arabic section of that grade level matches the Arabic level of that grade overseas.

	Beginners	Intermediate	Advanced	Total No of Students	Matches grade level overseas
Grade 5:	_____	_____	_____	_____	○Yes ○No
Grade 6:	_____	_____	_____	_____	○Yes ○No
Grade 7:	_____	_____	_____	_____	○Yes ○No

Thank you for your time, effort and thought in completing this survey.

Appendix B: Teacher Letter of Support

Dear Math Teachers,

Assalamu Alaikum,

My name is Samar Sarmini. I am a doctoral student in Math Curriculum & Instruction at the University of New Orleans, Louisiana. Thank you for taking the time to read this. The purpose of this study is to understand whether the language in which the word problem is presented in has an effect on the performance of bilingual Arab American students and whether these students' proficiency in their first language is related to their performance in solving mathematical word problems. Due to the limited research done on this particular population, the information gathered in this study will be used to encourage further research to better understand the academic needs of Arab American students and how their bilingualism can be utilized to enrich and support their classroom learning experience.

All measures will be taken to protect the confidentiality of the participants. Information from the tests and the survey will be coded by the principal investigator to protect anonymity. All reports and future publications will report information in a format that will ensure concealing the identity of all participants. All data will be securely stored in the office of the principal investigator's office in the Education Building at the University of New Orleans.

Your cooperation and support is extremely essential for the success of this project. You will be given Parent's Consent Form and Student's Letter of Assent in envelopes to be kindly passed out to each student in your classroom. Students are to be reminded to read, fill and return the envelopes the next day to be collected by you.

I will be present at the time of data collection, God willing. Each student participant will be asked to fill a short survey that will take no longer than 15 minutes. The students will be divided into one of four groups. Each student will be given two sets of 10 word problems each to solve on two separate days. Depending on which group the student is assigned to, students will either solve both sets in Arabic, in English, or one set in Arabic and the other in English. This will conclude the data collection for this study.

Since participation in this study is voluntary, some students might refuse to participate. To keep these students busy, they will be given alternate set of math word problems to solve. The solution to the word problems assigned to children not wishing to participate in the study will be automatically destroyed. The study is expected to take up approximately one class period on two separate days, depending on the time students spend on solving the word problems.

Your patience and understanding are greatly appreciated.

☐ I agree to support the administration of this study in my classroom.

☐ I do not agree to support the administration of this study in my classroom.

______________________________	____________________________	___/___/07
Signature of Teacher	Name of Teacher (print)	Date

Appendix C1: Parental Letter of Consent for Minors – English Version

To the parents of 5th, 6th, & 7th grade students:

Assalamu alaikum,

My name is Samar Sarmini. I am a graduate student under the direction of Professor Yvelyne Germain-McCarthy in the Curriculum & Instruction division of the Department of Education at the University of New Orleans. I am conducting a research study to understand whether the language in which a word problem is presented has an effect on the performance of bilingual Arab American students and how this is related to the student's level of comprehension in the Arabic language.

I am requesting your child's participation, which will involve students filling a short survey, and solving a set of 20 mathematical word problems, which may be in Arabic or in English. I am also requesting access to your child's standardized test scores for the English and Arabic subjects, and Mathematics. Two class periods will be designated to allow students to finish the above data requirements. The study will be conducted in the mathematics class for a period of approximately two hours. The math teachers will be collecting the parental and student consent forms from their students to give later to the researcher.

Your child's participation in this study is voluntary, but very necessary to the success of this project. If you choose not to have your child participates or to withdraw your child from the study at any time, there will be no penalty and it will not affect you child's math grade. Your child will be given opportunity to accept or decline participation in the study. If your child chooses not to participate or to withdraw from the study at any time, there will be no penalty. The results of the research study may be published, but your child's name will not be used.

Although there may be no direct benefit to your child, as a token of appreciation, students will be offered a sweet treat (chocolate bar) at the end of the study to express researcher's gratitude for participants and non-participants alike along with their mathematics teacher/s for putting the time and effort to allow this study to become a reality. More importantly, your child's participation will provide invaluable data that will help educators to better address the needs of the Arab American students in the current school system and be able to utilize their bilingualism to enrich and support their classroom learning experience.

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The risks associated with participating are minimal and include experiencing low levels of anxiety associated with solving math word problems. These risks are not greater than those ordinarily encountered in regular mathematics class period.

All measures will be taken to protect the confidentiality of the participants. Information from the tests and the survey will be coded by the principal investigator to protect anonymity. All reports and future publications will report information in a format that will ensure concealing the identity of all participants. All data will be securely stored in the office of the principal investigator's office in the Education Building at the University of New Orleans.

If you have any questions concerning the research study or your child's participation in this study, please call Dr. Richard Speaker at (504)280-6605.

If you have any questions about your rights or your child's rights as a participant in this research, or if you feel you or your child have been placed at risk, you can contact Dr. Richard Speaker at the University of New Orleans at (504)280-6605.

Yours truly,

Samar Sarmini

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I am the parent of ________________________ in 5th, 6th, 7th (circle one) grade.

☐ Yes, I allow my child to participate in this study.

☐ No, I do not allow my child to participate in this study.

☐ Yes, I allow access to my child's standardized test scores for English, Arabic, & math.

☐ No, I do not allow access to my child's standardized test scores for English, Arabic, & math.

☐ Yes, I allow my child to enjoy a sweet treat at the end of the study.

☐ No, I do not allow my child to enjoy a sweet treat at the end of the study.

If your child will participate, please have him/her complete the student consent form.

__________________________	________________________	___/___/07
Signature of Parent	Name of Parent (print)	Date
__________________________	Samar Sarmini	___/___/07
Signature of Investigator	Name of Investigator (print)	Date

THANK YOU FOR SUPPORTING THE EDUCATION OF THE

ARAB STUDENTS

Appendix C2: Parental Letter of Consent for Minors – Arabic Version

THE UNIVERSITY of NEW ORLEANS

بسم الله الرحمن الرحيم

طلب موافقة أولياء أمور الطلاب

إلى أولياء أمور الطلاب والطالبات في الصفوف الخامس والسادس والسابع، يحفظهم الله

السلام عليكم ورحمة الله وبركاته. وبعد

أفيدكم أنني أعتزم إجراء دراسة حول تأثير لُغَة طَرْح المسألة الحِسابيَّة ومهارة التلاميذ في حلها باللغة العربية بهدف تحسين عملية التَّعلم عند الطلاب العرب في المدارس في أميركا. وهذه الدراسة تأتي ضمن برنامج دراستي العليا في قسم التَّربيَة والتَّعليم في جامعة نيو أورْلِينْز تحت إشراف الدُّكتورة إيفلين جرْمِين- مَكَارْثي.

وتتضمن الدراسة ملء استطلاع قصير وحل مجموعة من الأسئلة مكونة من عشرين مسألة حسابية، قد تكون إما باللغة العربية أو باللغة الإنكليزية. ثم بعد ذلك سأقوم بالإطّلاع على العلامات الرَّسْمِيَّة المُوَحَّدَة في مادة اللُّغة الإنجليزية والعربية ومادة الرياضيات. المُتَوقَّع تخصيص حِصَّتَيْن لتمكين التلاميذ من ملء الاستطلاع وحلِّ المسائل. سيتم إجراء الدراسة في حصة الرياضيات لمدة ساعتين تقريبا. سيقوم معلم/معلمة الرياضيات بجمع طلبات إذن الأهالي والتلاميذ الموافقين على المشاركة في هذه الدراسة وإعطائها لاحقا للباحثة.

كما أفيدكم بأن مشاركة ابنكم/ابنتكم اختيارية ولا علاقة لها بالدرجات، إلا أنها بغاية الأهمِّيَّة لنجاح هذا البحث. ولابنكم/لابنتكم الحق في الانسحاب من الدِّرَاسة في أي وقت، ولن يكون هناك أي تأثير سَلْبِي ينعَكِسُ على علامتهم في مادَّةِ الرياضيات. كما أفيدكم أنه في حال نشر نتائج البحث فلن يُذكَرَ اسمُ الطالب/الطالبة المشاركين أبداً.

وفي نهاية الإختبار، وبالرغم من عدم وجود أي نفع مباشر للطالب أو الطالبة، ستوزع بعض الحلويات لكل التلاميذ المشاركين وغير المشاركين مع معلم أو معلمة الصف كتعبير عن امتنان الباحثة للوقت والجهد المبذولين لتحقيق هذه الدراسة.

إن مشاركة أولادكم ستوفِّرُ معلوماتٍ ذات قيمة فائقة تساعد المُرَبِّين لتوفير خَدَمات أفضل للتلاميذ العَرَب الموجودين في المدارس الأميركية والإستفادة من معرفتِهم للُغَتَيْن لدَعْمِ تحصيلِهم العِلْمِي. ولن يترتب على هذه المشاركة سلبيات تذكر إلا بعض القلق المعهود الذي قد يشعُرُ الطلاب به أثناء حلِّ المسائل الحسابية.

ستُبْذَلُ كلُّ الإجراءات الضَّرورية لحِماية هويَّة المشاركين حيث سأقوم بصِفَتِي الباحثة الأساسية بتقْيِيم الاستطلاع و حل المسائل الحسابية حفاظاً على خُصوصِيَّةِ المعلومات المُعْطاة من قِبَلِ التَّلاميذ. كما أنّ جميعَ التقارير والكِتابات حول هذا البحث سيكون بأسلوبٍ يُخْفِي هويَّة المشاركين، وستخزنُ المعلوماتِ المتعلقة بهذه الدراسة في مكتبِ المُشْرِفَة في مَبْنَى التَّعْليم في جامعة نيو أورلينز. لذا آمل منكم الإفادة عن الموافقة أو عدمها على مشاركة ابنكم/ابنتكم في هذه الدراسة.

ولمزيد من المعلومات، أو للإجابة عن الإستفسارات بخصوص هذا البحث، الرجاء الإتصال بالدكتور ريتْشَارد سْبِيكِر على الرقم: (504)280-6605 .

وتقبلوا خالص شكري وامتناني،

الباحثة/

Hasmini

سمر سرميني

THE UNIVERSITY of NEW ORLEANS

أنا ولي أمر الطالب/ الطالبة ____________________ في الصف_________________

- ☐ نعم، أسمح لابني/لابنتي بالمشاركة في هذه الدراسة.
- ☐ كلا، لا أسمح لابني/لابنتي بالمشاركة في هذه الدراسة.
- ☐ نعم، أسمح للباحثة الإطلاع على العلامات الرسمية الموحدة لابني/لابنتي في مادة اللغة الإنجليزية والعربية ومادة الحساب.
- ☐ كلا، لا أسمح للباحثة على الإطلاع على العلامات الرسمية الموحدة لابني/لابنتي في مادة اللغة الإنجليزية والعربية ومادة الحساب.
- ☐ نعم، أسمح لابني/لابنتي بالحصول على حلوى في نهاية هذه الدراسة.
- ☐ كلا، لا أسمح لابني/لابنتي بالحصول على حلوى في نهاية هذه الدراسة.

إذا كان ولدكم يود المشاركة، الرجاء التأكد من إكمال طلب موافقة الطلاب المُرْفَق.

___________________	______________________	___/___ / 2008
امضاء ولي الأمر	اسم ولي الأمر	التاريخ
___________________	سمر سرميني	___/___ / 2008
امضاء الباحثة	اسم الباحثة	التاريخ

Appendix D: Student Letter of Assent

Dear Student,

My name is Samar Sarmini. I am a graduate student under the direction of Professor Yvelyne Germain-McCarthy in the Curriculum & Instruction division of the Department of Education at the University of New Orleans. I am interested in learning about how you solve math word problems in Arabic and English.

I will ask you to complete a short survey and solve some math word problems. The whole process will take about two class periods. Your participation in this study is voluntary. Please talk to your parents about participation. If you choose not to participate or to withdraw from the study at any time, there will be no penalty and your math grade will not be affected. However, if you choose to participate, you will provide important input in discovering new knowledge that will help the Arab students do better in school. You will also enjoy a sweat treat at the end of the study, with your parent's permission.

If the results of the research are to be published, your name will not be used so you feel comfortable solving these word problems to the best of your ability.

If you have any questions concerning the research study, please call Dr. Speaker's at (504)280-6605.

If you do not wish to participate, you will be solving word problems assigned by the teacher.

☐ I have read the above information and agree to participate in this study.

☐ I have read the above information and do not agree to participate in this study.

Student's Name: ______________________________

Student's Signature: ______________________________

☺ THANK YOU FOR YOUR SUPPORT ☺

Appendix E1: Set 1 Word Problems With Solutions – English Version

STUDENT:____________________ **DATE: ___/___/08**

Do your best to solve **<u>each</u>** of the problems. Please, show all of your work. And, thank you again.

1. The Browns drove a total of 140 mi on Monday. They drove twice as far on Tuesday as they did on Monday. How many miles did they drive on both days?

   <u>Solution</u>:

   $140 \times 2 = 280$
   $280 + 140 = 420$
   They drove 420 miles on both days.

2. Four friends are measuring their heights. Sharon is shorter than Jenny. Jenny is taller than Bobby but shorter than Sammy. Who is the tallest?

   <u>Solution</u>:

   (Tallest) Sammy (= Wadi in the Arabic version)
   Jenny
   (Shortest) Sharon/Bobby

   Sammy is the tallest

3. Mr. Michael earns \$6 for each hour of work, and double that for each additional hour that exceeds 40 hours per week. He worked a total of 42 hours. Mr. Smith earns \$8 for each hour of work. He worked for 35 hours. Who will get paid more? By how much?

<u>Solution</u>:

Mr. Michael: $(6\times40)+(2\times12)=240+24=264$

Mr. Smith: $8\times35=280$

$280-264=\$16$

Mr. Smith will get paid more by \$16.

4. Charity spent \$3.26 for book covers, \$12.42 for a short story book, and \$2.65 for glue. She returned home with \$8.23. How much money did she have before going shopping?

<u>Solution</u>:

$8.23+2.65+12.42+3.26=\$26.56$

Charity had \$26.56 before going shopping.

5. At basketball practice, Justin scored 36 points. Brad scored 41 points. Kevin scored 10 fewer points than Justin and Brad combined. How many points did Kevin score?

<u>Solution</u>:

$(41+36)-10=67$

Kevin scored 67 points.

6. Mrs. Price's long distance phone calls usually last an average of 18 minutes. The long distance company offered her two plans:

   Plan A: the first three minutes cost \$2.25 and \$0.30 for each additional minute; Plan B: flat rate of \$0.50 per minute. Which plan is cheaper? By how much?

   <u>Solution</u>:

   Plan A: $2.25+(0.30\times15)=2.25+4.50=\$6.75$

   Plan B: $0.50\times18=\$9.00$

   $9.00 - 6.75 = \$2.25$

   Plan A is cheaper by \$2.25.

7. John thought of a number, then subtracted 35 from it, then multiplied the difference by 3, then added 60 to the product, and got 180. What was the number John thought of?

   <u>Solution</u>:

   $(X-35)\times3+60=180$

   ⇨ $180-60=120$

   $120\div3=40$

   $40+35=75$

8. Lynn, Francine, Eileen, Susan, and Nancy ran in a race. Susan finished the race before Nancy. Francine finished before Susan but after Eileen. Lynn finished before everyone but Eileen. Who was the first, second, and third to finish the race?

Solution:

1st place: Eileen
2nd place: Lynn
3rd place: Francine
4th place: Susan
5th place: Nancy

9. There were 412 men on a train. There were four times as many men as women. How many women were on the train?

Solution:

$412 \div 4 = 103$

There were 103 women on the train.

10. Lisa has 11 quarters. She has twice as many dimes as quarters, and 5 fewer nickels than dimes. She has the same number of pennies as the other coins combined. How many of each coin does Lisa have?

Solution:

11 quarters
22 dimes
17 nickels
50 pennies

Appendix E2: Set 1 Word Problems – Arabic Version

الطالب: ________________ **التاريخ**: __/__/ 08

ابذِل جُهدك في حلِّ المسائلِ التالية **كلها**. أظهر طريقة الوصول إلى الحَل، ولكم جزيل الشكر.

1. رَكِبَتْ عائلة ياسين السَّيَّارَةَ مَسَافَة 140 مِيلٍ يَوْمَ الإثنَيْن. ورَكِبُوا السَّيَّارَةَ يَوْمَ الثلاثاء ضِعْفَ المَسَافَةِ التِي رَكِبُوها الإثنَيْن. كَمْ مِنَ الأمْيَالِ قادُوا السَّيَّارَةَ في اليَوْمَيْن؟

2. أرْبَعَة أصْدِقاء يَقِيسُونَ طولهُم. شَادْيَة أقصَرُ مِنْ جِهَان. جِهَانُ أطولُ مِنْ قاسِم ولِكِنْ أقصَرُ مِنْ وَدِيع. مَن الأطوَل؟

3. السَّيِّدُ مَجْدِي يَكسِبُ 6$ لِكُلِّ سَاعَةٍ مِنَ العَمَل وضِعْفَ هذا المَبْلغ لِكُلِّ سَاعَةٍ إضَافِيَّةٍ بَعْدَ تَخَطِّي 40 سَاعَة عَمَلٍ في الأسْبُوع. اشْتَغَلَ مَا مَجْمُوعُهُ 42 سَاعَة. السَّيِّدُ خَالِدُ يَكْسِبُ 8$ لِكُلِّ سَاعَةِ عَمَل. اشْتَغَلَ 35 سَاعَة. مَنْ سَيَتَقَاضَى مَبْلَغاً أكبَر؟ وبكم؟

4. أنْفَقَتْ مُنَى 3.26$ ثَمَن غِلافات كُتُب، و 12.42$ ثَمَن كِتَابٍ قَصَصِيٍّ قَصِير، و 2.65$ ثَمَن غِرَاء. رَجَعَتْ إلى المَنْزِل ومَعَهَا 8.23$. كَمْ كَانَ مَعَهَا مِنَ النُّقودِ قبْلَ أنْ تَذْهَبَ لِلتَّسَوُّق؟

5. أثْنَاءَ تَدْرِيبِ كرَةِ السَّلَّة، سَجَّلَ بِلالُ 36 نُقطة. و سَجَّلَ إبْرَاهِيمُ 41 نُقطة. سَجَّلَ عُمَرُ 10 نِقَاطٍ أقلُّ مِنْ مَجْمُوع نِقَاطِ بلال و إبْرَاهيم. كَمْ نُقطة سَجَّلَ عُمَر؟

6. يَبْلغُ طُولُ المُخَابَرَاتِ الدُّوَلِيَّة لِلسَّيِّدَةِ إقبَال مُعَدَّلَ 18 دَقِيقة. عَرَضَتْ عَلَيْهَا شَرِكَة لِلْمُكَالَمَاتِ الدُّوَلِيَّة بَرْنَامَجَيْن لِلإتِّصَال:

البَرْنَامَجُ أ: أوَّلُ ثَلاثَةِ دَقَائِقٍ تُكَلِّفُ 2.25$ ثُمَّ 0.30$ لِكُلِّ دَقِيقَةٍ إضَافِيَّة.

البَرْنَامَجُ ب: سِعْرٌ ثَابِتٌ يَبْلُغُ 0.50$ لِلدَّقِيقَة.

أيُّ البَرْنَامَجَيْن أقلُّ كِلفَة؟ وبِكَم؟

7. فَكَّرَ مُحَمَّدُ برَقْمٍ، ثُمَّ طَرَحَ مِنْهُ 35، ثُمَّ ضَرَبَ الفَارِقَ ب 3، ثُمَّ أضَافَ 60 إلى الحَاصِلِ، فَحَصَلَ عَلَى 180. مَا هُوَ الرَّقْمُ الَّذِي فَكَّرَ بِهِ مُحَمَّد؟

8. تَرْكضُ الصَّدِيقَاتُ لِينَا وفَرَح ورَنَا وسَوْسَنُ وسَمَاحُ في سِبَاق. وَصَلَتْ سَوْسَنُ إلى خَطِّ النِّهَايَةِ قَبْلَ سَمَاح. وَصَلَتْ فَرَحُ قَبْلَ سَوْسَنُ ولكِن بَعْدَ رَنَا. وَصَلَتْ لِينَا قَبْلَ الجَمِيع ما عَدَا رَنَا. مَن الفَائزاتُ بالمَرْتَبَةِ الأولى والثَّانِيَة والثَّالِثَة في السِّبَاق؟

9. هُنَاكَ 412 رَجُلا عَلَى مَتن القِطَار. عَدَدُ الرِّجَال كَانَ أرْبَعَةِ أضْعَافِ عَدَدِ النِّسَاء. كَمْ عَدَدُ النِّسَاءِ اللَّاتِي كُنَّ عَلَى مَتْن القِطَار؟

10. لَدَى شَيْمَاءُ 11 قِطْعَة مِنَ ال"رُبْع دولار". مَعَهَا مِنْ قِطع ال"عَشَرَةِ سَنْتَاتٍ" ضِعْفَ عَدَدِ ال"رُبْع دولار"، ومِنْ قِطع ال"خَمْسَةِ سَنْتَاتٍ" 5 أقلَّ مِنْ قِطع ال"عَشَرَةِ سَنْتَاتٍ". مَعَهَا مِنْ قِطع ال"واحِدِ سَنْتٍ" نَفْس مَجْمُوع بَقِيَّة القِطعِ النَّقْدِيَّة. كَمْ عَدَدُ كُلٍّ مِنَ القِطَع النَّقدِيَّة مَعَ شَيْمَاء؟

Appendix F1: Set 2 Word Problems With Solutions – English Version

STUDENT:__________________ **DATE: ___/___/08**

Do your best to solve **each** of the problems. Please, show all of your work. And, thank you again.

1. Five students stood in line to go on the school bus. Nicole stood first in line; Lara stood between Sarah and Ron; and Sarah stood behind Nicole. Where does Samantha stand in line?

   Solution:

   (Front)
   Nicole
   Sarah
   Lara
   Ron
   Samantha (=Samar in the Arabic version)
   Samantha/Samar stands last in line.

2. Freddie collected 45 stamps in the month of April, and twice as many in May. How many stamps in all did he collect in both months?

   Solution:

   $45 \times 2 = 90$
   $45 + 90 = 135$ stamps
   Freddie collected 135 stamps in both months.

3. Omar thought of a number, he then subtracted 25 from it, multiplied the difference by 5, added 50 to the product and got 225. What was the number Omar thought of?

<u>Solution</u>:

$(x-25)\times 5+50=225$

⇨ $225-50=175$

$175\div 5=35$

$35+25=60$

Omar thought of the number 60.

4. Mr. John wants to rent a car to go on a trip. The cost is \$35 per day as long as the mileage does not exceed 100 km, otherwise he has to pay \$5 for each extra km. Another option is to pay \$60 for each day. Which option is the best, if the trip is going to last 3 days and the total distance will be 150 km?

<u>Solution</u>:

1st option: $(3\times 35)+(5\times 50)=105+250=$ \$355

2nd option: $3\times 60=180$

2nd option is the best.

5. There were 46 women and 35 men attending a wedding. The number of children attending the same wedding was 15 fewer than the number of men and women combined. How many children were attending this wedding?

Solution:

$(46+35)-15=66$

There were 66 children attending the wedding.

6. A large car consumes 3 times the amount of gas a small car does per year. Mr Smith used up 2700 Liters of gas by driving the large car. How much gas would he have used by driving the small car instead?

Solution:

$2700 \div 3=900$

The small car consumes 900 Liters of gas.

7. Michael planted apple, plum, cherry and pear trees in rows. The apple trees are the closest trees to the pear trees. The apple trees are to the right of the cherry trees, and the plum trees are to the left. What is the order of the trees from left to right?

Solution:

(Left) Plum Cherry Apple Pear (Right)

8. Mira spent \$15.60 for books, and \$9.38 for pencils and \$3.12 for sweets. She returned home with \$6.50. How much money did Mira have before going shopping?

<u>Solution</u>:

$15.60+9.38+3.12+6.50=34.60$

Mira had \$34.60 before going shopping.

9. Mary has 15 white marbles. She has twice as many blue marbles as white marbles, and 7 fewer red marbles than blue marbles. How many red marbles does she have?

<u>Solution</u>:

White marbles:	15
Blue marbles:	30
Red marbles:	23

10. William pays \$35 a month for 400 minutes of cell phone use and \$0.40 for each extra minute. His friend Andrew pays \$0.20 per minute for cell phone usage. If each used a total of 500 minutes in one month, who would pay more? By how much?

<u>Solution</u>:

William: $35+(0.40\times100)=35+40=75$

Andrew: $0.20\times500=100$

$100 - 75 = \$25$

Andrew paid more by \$25.

Appendix F2: Set 2 Word Problems – Arabic Version

الطالب: ________________ **التاريخ**: __/__/ 08

ابذِل جُهدك في حلِّ المسائلِ التالية **كلها**. أظهِر طريقة الوصولِ إلى الحَل ، ولكم جزيل الشكر.

1. وَقفَ 5 تَلاميذٍ في صَفٍّ لِصُعُودِ سَيَّارَةِ المَدْرَسَة. وَقفَتْ نَدَى فِي مُقدِّمَةِ الصَّف، ولارا بَيْنَ سَارَة ورَانِي وسَارَة خَلفَ نَدَى. أيْنَ تَقِفُ سَمَر فِي الصَّف؟

2. جَمَعَ فَادِي 45 طابع بَرِيدِيٍّ فِي شَهْر نيسَان. وجَمَعَ في شَهْر أيَّار ضِعْفَ ما جَمَعَ في شَهْر نيسان. كَمْ طابع بَرِيدِيٍّ جَمَعَ فِي الشَّهْرَيْن؟

3. فَكَّرَ عُمَرُ بعَدَدٍ، طرَحَ مِنْهُ 25 وضَرَبَ الفَرْقَ ب 5 وجَمَعَ إلى الحَاصِلِ 50 فَحَصَلَ عَلى 225. ما هُوَ العَدَدُ الّذِي فَكَّرَ بِهِ عُمَر؟

4. يُريدُ السَّيِّدُ خَلِيل اسْتِئْجَارَ سَيَّارَةٍ لِلقِيَامِ برِحْلة. كِلفَة الأجْرَةِ اليَوْمِيَّةِ 35$ شَرْط أنْ لا تَتَعَدَّى المَسَافَة 100 كِيلومِتر. وَإلا عَلَيْهِ أنْ يَدْفَعَ مَبْلغَ 2$ عَنْ كُلِّ كِيلومِتر زِيَادَة. وكَانَ هُنَاكَ خَيَارٌ آخَرُ وهُوَ أنْ يَدْفَعَ 60$ أجْرَةَ اليَوْم الوَاحِد. مَا هُوَ الخَيَارُ الأفضَلُ لِلسَّيِّدِ خَلِيل، إذا عَلِمْنَا أنَّ الرِّحْلة تَسْتغْرِقُ 3 أيَّامٍ وأنَّ المَسَافة التِي يُريدُ قطعَهَا هي 150 كِيلومِتراً؟

5. حَضَرَ حَفلة العُرْس 46 مِنَ النِّسَاء، و35 مِنَ الرِّجَال. عَدَدُ الأوْلادِ الّذِينَ حَضَرُوا كانَ 15 أقلَّ مِنْ مَجْمُوع عَدَدِ الرِّجَال والنِّسَاء. فكَمْ كانَ عَدَدُ الأولادِ الّذِينَ حَضَرُوا حَفلة العُرْس؟

6. تَسْتَهْلِكُ السَّيَّارَة الكَبيرَة 3 أضْعَافِ مَا تَسْتَهْلِكُهُ السَّيَّارَةُ الصَّغِيرَةُ مِنَ البنْزين سَنَوِيّاً. اسْتَهْلَكَ السَّيِّدُ نَادِرُ 2700 ليتر مِنَ البنْزين باسْتِعْمَالِهِ السَّيَّارَةَ الكَبيرَة. فَكَمْ يَسْتَخْدِمُ السَّيِّدُ نَادِر مِنَ البنْزين إذا اسْتَعْمَلَ السَّيَّارَةَ الصَّغِيرَة؟

7. زَرَعَ مَازِنٌ تُفَّاحاً، وخَوْخاً، وكَرَزاً، وإجَّاصاً في صُفُوف. أقْرَبُ الأشْجَارِ إلى الإجَّاص هِيَ التفاح. التفاحُ إلى يَمِينِ الكَرَز، والخَوْخُ إلى اليَسَار. ما تَرْتِيبُ الأشْجَارِ مِنَ اليَسَارِ إلى اليَمِين؟

8. صَرَفَتْ لَمْيَاءُ 15.60 دُولاراً أميركِيّاً لِشِرَاء الكتب، و 9.38 دُولاراً أمِيركِيّاً في شِرَاءِ الأقلامِ و 3.12 دُولاراً أميركِيّاً في الحَلوَى، ورَجَعَتْ إلى البَيْتِ ومَعَها 6.50 دُولاراً أمِيركِيّاً. فَكَمْ دُولاراً أميركِيّاً كان مَعَها قَبْلَ الذَّهَابِ إلى السُّوق؟

9. عِنْدَ مَرْيَم 15 كِلَّةٍ بَيْضَاء. وعِنْدَها ضِعْفَ هذا العَدَدِ مِنَ الكِلل الزَّرْقاء، وعِنْدَها مِنَ الكِلل الحَمْراء 7 أقل مِنَ الكِلل الزَّرْقاء. مَا عَدَدُ الكِلل الحَمْرَاء الَّتِي عِندَ مَرْيَم؟

10. يَدْفَعُ فَريدُ 35$ شَهْرِيّاً مُقابلُ اسْتِعْمَال هَاتِفَهُ الخَلويّ مُدَّةَ 400 دَقِيقَة ومِنْ ثَمَّ يَدْفَعُ 0.40$ على كُلِّ دَقِيقَةٍ إضَافِيَّة. أمَّا صَدِيقهُ سَامي فَيَدْفَعُ 0.20$ على كُلِّ دَقِيقَةٍ مِن اسْتِعْمَالِ هاتِفِهِ الخَلوي. إذا اسْتَعْمَلَ كُلٌّ مِنْهُمَا هَاتِفَهُ الخَلويّ مُدَّةَ 500 دَقِيقَةٍ في أحَدِ الأشْهُر، مَن الَّذِي سَيَدْفَعُ مَبْلغاً أكبَر؟ وبكَم؟

Appendix G: Student Survey

Please fill in the information to the best of your ability.

1. Name/ID No: ____________________________
2. Grade: ________________
3. Which language is more comfortable to use when you are speaking? (*check only one*)

   ○ Arabic ○ English

   Were you born in the United States? ○ Yes ○ No
4. If no, how old were you when you came to the United States?

   ____
5. What language do you speak at home? (*check only one*)

   _____ only English, no Arabic

   _____ mostly English, little Arabic

   _____ equal amount of English and Arabic

   _____ mostly Arabic, little English

   _____ only Arabic, no English
6. What language do you speak with your Arabic speaking friends/ relatives in the United States? (*check only one*)

   _____ only English, no Arabic

   _____ mostly English, little Arabic

   _____ equal amount of English and Arabic

   _____ mostly Arabic, little English

   _____ only Arabic, no English

7. How well do you **SPEAK** Arabic compared to other Arab students overseas?

   ○ Very well ○ Well ○ Very little ○ Not well at all
8. How well do you **READ** Arabic compared to other Arab students overseas?

   ○ Very well ○ Well ○ Very little ○ Not well at all
9. How well do you **WRITE** Arabic compared to other Arab students overseas?

   ○ Very well ○ Well ○ Very little ○ Not well at all

☺ Thank you for your effort! ☺

Appendix H: IRB Approval Form

University Committee for the Protection of Human Subjects in Research *University* **of New Orleans**

Campus Correspondence

Dr Yvelyne Germain-McCarthy

Samar El-Rifai

11/8/2007

RE: Exploring the relationship between the level of proficiency of bilingual students' first and second languages and their competence in solving word problems in both languages

IRB#: 01feb07

The IRB has deemed that the research and procedures are compliant with the University of New Orleans and federal guidelines.

Please remember that approval is only valid for one year from the approval date. Any changes to the procedures or protocols must be reviewed and approved by the IRB prior to implementation.

If an adverse, unforeseen event occurs (e.g., physical, social, or emotional harm), you are required to inform the IRB as soon as possible after the event.

Best of luck with your project!

Sincerely,

Laura Scaramella, Ph.D.

Chair, University Committee for the Protection of Human Subjects in Research

VITA

Samar El-Rifai Sarmini lived in Beirut, Lebanon until she got married to Dr. Mahmoud Sarmini in 1991. They lived in Greenville, North Carolina for three years. In 1994, the couple moved to New Orleans, Louisiana and resided there ever since. Samar Sarmini has three wonderful boys: Mohammad, 15; Bilal, 11, and Omar, 5. Samar received her B.S. in Computer Science from the American University of Beirut, in 1990. In 1996, she received her M.Ed. in curriculum and instruction with a focus on computer education, and in 2009, a Ph. D. in curriculum and instruction with a focus on mathematics education. Both degrees were completed at the University of New Orleans with a 4.0 GPA. Samar is also a member of the honor society of Phi Kappa Phi.

Samar Sarmini worked as the principal of a newly established full-time Islamic school in Gretna, LA, from 2000 to 2003. She then had to excuse herself from the administrative duties in order to better care for her third newborn. She continued working on her Ph. D. degree while teaching mathematics part-time at the Islamic school. Samar has experience in teaching mathematics for grades ranging from third grade to tenth grade for over a decade.