THE EFFECTS OF A TWO-WAY DUAL LANGUAGE IMMERSION ENVIRONMENT ON ELEMENTARY MATHEMATICS TAKS TEST SCORES IN TEXAS: AN OVERALL COMPARISON AND AN ANALYSIS OF QUESTIONS WITH AND WITHOUT A VISUAL PROMPT

A Dissertation

by

SHARI A. BECK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2011

Major Subject: Curriculum and Instruction

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ABSTRACT

The Effects of a Two-Way Dual Language Immersion Environment on Elementary Mathematics TAKS Test Scores in Texas: An Overall Comparison and an Analysis of Questions With and Without a Visual Prompt. (May 2011)

Shari A. Beck, B.S., Texas A&M University;

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With the dynamics of the growing population of native Spanish-speaking students in America's public schools, two-way dual language immersion programs are increasing in number. A series of observations and interviews in a dual language program by the researcher led to the identification of the use of visuals as a prevalent component integrated in instruction. This dominant instructional strategy led to questions of how visuals might affect student performance. Previous studies had not focused specifically on questions with a visual prompt and questions without a visual prompt.

The purpose of this study was to answer several questions focused on differences in student performance on nonvisual and visual questions. The research questions used to achieve this purpose included a comparison of Mathematics TAKS Test scaled scores for students in a two-way dual language immersion program and students enrolled in a monolingual educational program, an analysis comparing these two groups of students on nonvisual and various categories of visual questions, an analysis of the performance of both groups of students based on the comparison of nonvisual questions to subsets of visual questions, and an analysis of an interaction effect and main effects of question type and group based on educational setting.

A quasi-experimental design with static-group comparison was used for the purposes of this study. Data were collected from the Texas Education Agency [TEA] for all students who took the Spring 2009 version of the Grade 3 or Grade 4 Mathematics TAKS Test in English or Spanish. Data from a total of 6,904 students were used in the study. Data were analyzed based on descriptive statistics and ANOVAs.

A statistically significant difference was found in overall scaled score comparisons between the two groups of students on the Spanish version of the Grade 4 Test. Major findings of the study included a higher performance shown on most subsets of visual questions compared to nonvisual questions for both groups of students involved in this study. Two-way dual language immersion students scored higher than students in a monolingual English program on most subsets of visual questions, but no interaction effect occurred between question type and group.

DEDICATION

To all who have stood behind me with support and to all who have walked beside me throughout this journey, I dedicate this project. I have finished the “fourth quarter”!

ACKNOWLEDGEMENTS

I always dreamed of returning to graduate school to earn this degree, but I could never see the path until possibly later in life. While sitting outside of the Baylor Hospital ICU following my husband's heart surgery, I was quickly reminded of the fragility of life and the lack of a guarantee for tomorrow. Thus, this began my journey of what seemed impossible at times. I have many to acknowledge and thank for all they have done for me along the path of this journey.

First and foremost, I thank God for the strength, courage, and endurance to achieve all that I have done. I truly can say that there were many times along the path that the Lord carried me.

Secondly, I thank my committee for their professional knowledge, mentoring, and support throughout the entire journey. I especially thank my co-chairs, Dr. Janie Schielack and Dr. Lynn Burlbaw, for their guidance throughout my entire graduate school endeavor.

I personally thank Dr. Janie Schielack for being my strength, encourager, and continuous contact for communication prior to and throughout my journey. I honestly do not believe that I could have reached this far without her. There were many times throughout this process that she knew exactly what to say to help me when I needed to hear her words the most. She is such a role model for me, and I have always remembered her encouraging words about how life events will happen whether I am in graduate school or not. Those life events certainly did not cease during this journey, and her encouragement helped me get through those difficult times.

I thank Dr. Lynn Burlbaw for believing in me and agreeing to co-chair my committee. He has been such a dependable source of information and an open line of communication for me. He has taught me how to begin to accept the gray areas throughout life, and I will always remember how he encouraged me to "enjoy the ride."

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I am thankful to Dr. Vanessa Huse for the encouragement to go back to school. I thank my sister-in-law, Dr. Nancy Beck-Young, and my brother-in-law, Dr. Mark Young, for their continuous support and encouragement. I am appreciative to Nancy for the open line to call anytime I had questions and frustrations. I also thank my parents-in-law, John and Kenna Beck, for their positive words of encouragement and the pride they have shown for me throughout this process. I am sad that my father-in-law was not able to see me finish the journey, but I know how proud he would have been for me.

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Finally, I am thankful for my family and feel blessed to have had their love and support throughout this journey. I thank my three wonderful children, John Keitt Beck, III, Rudy Andrew Beck, and Sarah Ann Beck for their love and understanding when I had to focus on school or be away from them for class. I will always remember how John and I would sometimes do homework together and how Rudy would constantly check on the grades that I received on assignments and in my classes. Sarah provided many smiles and hugs at times when I simply needed a break. I especially want to thank my husband, Dr. John Keitt Beck, Jr., for his love and support during what probably seemed like several long years of late hours, focus, and studying for me. I am thankful for the numerous times that he gave me the time and freedom to work on graduate school assignments or research while maintaining a hectic schedule of work and taking care of our family. I thank him for his open ears at times when I just needed to vocalize my thoughts, fears, and frustrations. Most of all, I thank him for being my best friend and supporter at times when I needed encouragement the most. He overcame many obstacles with his health and has been by my side during this journey.

As I close this chapter of my life and end this journey, I look back with much gratitude for all who have done so much to help me along the way. I acknowledge that I could not have completed this goal without each of you by my side.

NOMENCLATURE

ELL	English Language Learner
FERPA	Family Educational Rights and Privacy Act
LEP	Limited English Proficiency
NAEP	National Assessment of Educational Progress
NCTM	National Council of Teachers of Mathematics
NRC	National Research Council
TAKS	Texas Assessment of Knowledge and Skills
TEA	Texas Education Agency
TEKS	Texas Essential Knowledge and Skills

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CHAPTER I

AN INTRODUCTION

Students today live in a dynamically changing world where boundaries have been flattened by technology and mathematics education has often fallen behind in empowering students to be mathematically competent in an increasingly digital world (Friedman, 2005). The population within America's public school system is also changing (Planty et al., 2009). With the dynamics of the growing population of native Spanish-speaking students in America's public schools, two-way dual language immersion programs are increasing in number. While previous research has been conducted with a focus on the mathematics achievement of students enrolled in a two-way dual language immersion program (Dow, 2008; Egan, 2007; Lambert, Genasee, Holobow, & Chartrand, 1993; Lindholm & Fairchild, 1988; Medrano, 1988), questions arise specifically about the effects of possible instructional strategies being utilized in the teaching of two languages. While research has focused on cognitive abilities of students in bilingual education programs (Cummins, 1974; Garcia, 1986; Lee, 1996; Lindholm-Leary, 2005), very few studies examine data at the third- and fourth-grade levels for possible sources of higher mathematics performance on standardized tests mandated at the state level. A series of observations and interviews in a dual language

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This dissertation follows the style of *Journal for Research in Mathematics Education*.

program by the researcher led to the identification of the use of visuals, such as gestures, diagrams, and pictures, as a prevalent component integrated in instruction in a dual language environment. This dominant instructional strategy led to questions of how visuals might affect student performance on an assessment of learning outcomes. While previous studies had targeted mathematics achievement in general (Dow, 2008; Egan, 2007; Lambert et al., 1993; Lindholm & Fairchild, 1988; Medrano, 1988; Snyder, 2009), studies did not focus specifically on questions with a visual prompt and questions without a visual prompt. This study seeks to answer several questions focused on the scores and subsets of scores of dual language students who took the English or Spanish version of the Grade 3 or Grade 4 Mathematics Texas Assessment of Knowledge and Skills (TAKS) Test in the state of Texas during the Spring 2009 administration of the test.

Rationale for the Study

Dual Language Immersion Programs on the Rise in American Schools

The population of students in public school across America is changing with an increasing number of Hispanic students (Planty et al., 2009). According to Livingston (2008), 10.8 million children speak a language other than English at home, and 7.8 million of these children speak Spanish. This rising enrollment of Hispanic students combined with the large number of children who speak Spanish at home has resulted in the increase of alternate instructional approaches including two-way dual language immersion programs. In this type of educational program, instruction is given in two different languages throughout each week, with the language of instruction often being based on the subject being taught (Howard, Sugarman, & Christian, 2003; Gómez, Freeman, & Freeman, 2005; Garcia & Jensen, 2006; Barnett, Yarosz, Thomas, Jung, & Blanco, 2007).

Studies Focused on Mathematics Achievement, Bilingual Education, and Visuals

Previous studies on mathematics achievement have shown a lag in scores in reading and mathematics for Hispanic students (Snyder, 2009). Perie, Sherman, Phillips, and Riggan (2000) stated that the non-English speaking students in the United States exhibit lower academic performance. Recent dissertation studies focused on elementary students in immersion programs indicate higher mathematics scores for immersion students compared to students not enrolled in an immersion program (Dow, 2008; Egan, 2007). Other studies focused on mathematics achievement have shown higher results for students in a bilingual program compared to a monolingual control group (Lambert et al., 1993).

Positive effects of bilingual education have been shown for over 20 years (Lindholm & Fairchild, 1988; Medrano, 1988). Lambert et al. (1993) implies that a transfer between languages occurs based on the finding that bilingual education learners scored much higher on a mathematics test involving conceptual and computational knowledge than the monolingual control groups.

Research provides evidence advocating for the use of visuals as an instructional tool (Ainsworth, Bibby, & Wood, 2002; Coelho, 2004; Flevares & Perry, 2001; Goldin

& Kaput, 1996; Lowrie & Kay, 2001; Seng & Chan, 2000). Smith and Ragan (2005) describe how students learn through their attention to stimuli in the learning environment, which can include sights and tactile stimuli. Coelho (2004) stressed the use of visual and contextual support for beginning language learners. Research that focuses on mathematics instruction with visuals indicates that students use visuals for solving problems (Shama & Dreyfus, 1994). Other studies have also shown positive results for student performance in mathematics as a result of the use of visuals (Finnan-Jones, 2007; Lee & Zentall, 2002). The National Research Council [NRC] describes how visual information helps organize brain development and declares that this type of "…external information is even more important for later cognitive development" (2000, p. 118).

Section Summary

Therefore, with the emergence of educational programs such as a two-way dual language immersion program as a result of a changing population of students in American schools (Hussar & Bailey, 2008; Planty et al, 2009), new questions related to mathematics education need to be explored. Because the learning environment in a two-way dual language immersion program includes both native English and native Spanish speakers who are instructed in each language approximately half of the time, the use of visuals arise as a prominent instructional tool in the classroom (Beck & Cifuentes, 2010). Previous studies have shown that Hispanic students and non-English speaking students in the United States exhibit lower academic performance (Perie et al., 2000; Snyder, 2009). Positive effects of bilingual education (Lambert et al., 1993; Lindholm

& Fairchild, 1988; Medrano, 1988) and evidence supporting the use of visuals in instruction exists (Ainsworth et al., 2002; Coelho, 2004; Flevares & Perry, 2001; Goldin & Kaput, 1996; Lowrie & Kay, 2001; Seng & Chan, 2000). However, research has not combined the use of visuals with mathematics instruction in a bilingual educational program such as a two-way dual language immersion program.

Statement of the Problem

With the dynamics of the growing population of native Spanish-speaking students in America's public schools, two-way dual language immersion programs are growing. A two-way dual language immersion program is one type of bilingual educational program with goals focused on developing students to become bilingual while most other bilingual programs have goals centered on helping students learn to speak English as their second language. The first two-way dual language immersion program in the United States began in 1963 with a French/English program in Massachusetts and a Spanish/English program in Florida (Howard et al., 2003). The growth of new programs was slow for about the first twenty years with a recent dramatic increase (Howard et al., 2003). The Center for Applied Linguistics (2010a) maintains a directory of two-way dual language immersion programs, listing 359 programs in 28 states plus Washington D. C. These dual language immersion programs raise questions about how this different educational environment might affect the academic achievement of students; in particular, regarding how the development of a second language and the use of visuals in this type of learning environment might affect mathematics achievement.

While research has focused on cognitive abilities of students in bilingual education programs (Cummins, 1974; Garcia, 1986; Lee, 1996; Lindholm-Leary, 2005), very few studies examine data at the third- and fourth-grade levels for possible sources of higher mathematics performance on standardized tests mandated at the state level. This presents a gap in the research literature with a need for studies focused on the academic achievement of third- and fourth-grade students in a bilingual program. Other studies have also targeted mathematics achievement in general and did not focus specifically on subsets of questions based on identified types (Dow, 2008; Egan, 2007; Lambert et al., 1993; Lindholm & Fairchild, 1988; Medrano, 1988; Snyder, 2009). More specifically, these studies did not focus on the separation of visually prompted questions from those that did not have a visual prompt (Dow, 2008; Egan, 2007; Lambert et al., 1993; Lindholm & Fairchild, 1988; Medrano, 1988; Snyder, 2009).

Thus, instruction in two different languages with the different educational environment of a two-way dual language immersion program and the unknown effect of this program with the inclusion of visuals in mathematics instruction create a need for research. This identified need combined with the lack of studies focused specifically on dual language students in the third and fourth grade justify a need for a study focused specifically on the performance of dual language immersion students on visual and nonvisual questions in the third and fourth grade.

Purpose Statement

The purpose of this study was to determine if students in a two-way dual language immersion program perform higher in mathematics overall and on mathematics questions with certain types of visual prompts compared to questions that do not have a visual prompt due to having the aspect of visual reinforcement in the learning environment. This study also sought to determine if question type and instructional environment had main effects or an interaction effect on the Grade 3 or Grade 4 Mathematics TAKS Test scores.

Research Questions

Specifically, the study sought to investigate the following research questions:

1. Are the Grade 3 and Grade 4 Mathematics TAKS Test scaled scores different for students who participated in a two-way dual language immersion environment from those scaled scores of students in a monolingual English program?
2. Are percentages of correct responses on nonvisual questions and various categories of visual questions on the Grade 3 and Grade 4 Mathematics TAKS Test different for students who participated in a two-way dual language immersion environment from those percentages of correct responses of students in a monolingual English program?
3. For students who participated in a two-way dual language immersion environment, are the percentages of correct responses on the Grade 3 and

Grade 4 Mathematics TAKS Test for questions with certain types of visual prompts different from the percentages of correct responses for questions without a visual prompt?

4. For students in a monolingual English program, are the percentages of correct responses on the Grade 3 and Grade 4 Mathematics TAKS Test for questions with certain types of visual prompts different from the percentages of correct responses for questions without a visual prompt?

5. Are there any main effects or an interaction effect between question type (visual category versus nonvisual) and instructional environment (two-way immersion versus monolingual education program) on the Grade 3 and Grade 4 Mathematics TAKS Test scores?

This study is relevant to theory and practice because mathematics test results for students from a two-way dual language immersion environment were compared to mathematics test results for students participating in a monolingual English program. More specifically, a focus on mathematics questions with and without a visual prompt revealed if the type of question has an effect on performance for two different learning environments, two-way dual language immersion and monolingual education. Finally, the study revealed if main effects or an interaction effect between question type and instructional environment exists as a possible result of some aspect of the bilingual educational environment of a two-way dual language immersion program.

Conceptual Framework

Results from the Spring 2009 version of the Mathematics TAKS Test for all third- and fourth-grade students in the state of Texas were obtained from the TEA. For each student, the researcher received a coding for sex, ethnicity, economic disadvantage, and bilingual indicator. The researcher also received a scaled score, test language version, and item analysis data for every student.

Item analysis results for students in two-way dual language immersion and monolingual education programs were organized, studied, broken into subgroups, compared, and analyzed. This study sought to extend and link previous research in both mathematics education and bilingual education by providing insight about the educational setting of a two-way dual language immersion program and the effects on mathematics instruction. Previous studies had focused on mathematics in a various types of bilingual education programs, but none had specifically compared overall performance of third- and fourth-grade students in a two-way dual language immersion environment (Lambert et al., 1993; Lindholm & Fairchild, 1988; Medrano, 1988). None of these studies had targeted mathematics questions with a visual prompt compared to mathematics questions without a visual prompt. Thus, this study attempted to search for effects of educational environment and question type on mathematics achievement for third- and fourth-grade students on the Mathematics TAKS Test.

Limitations and Delimitations

A limitation of this study resulted from the exploratory nature of this study based on the existing enrollment of students in either a two-way dual language immersion program or a monolingual education environment. The researcher had no control over academic ability of the students, instructional design of the programs, teachers in the programs, or any factors leading to or prohibiting academic achievement. Thus, the researcher compensated for these limitations by randomly selecting the same number of students in a monolingual education program for each version of the test to match the number of students in the two-way dual language immersion program for the same version of the test.

Delimitations of this study resulted from the choice to focus the study on third- and fourth-grade students who took the Spring 2009 Mathematics TAKS Test in the state of Texas.

Instrumentation

The Mathematics TAKS Test in the state of Texas is a criterion-referenced test based on the TEKS objectives as outlined by the state (TEA, 2010). The test is "…designed to measure to what extent a student has learned, understood, and is able to apply the important concepts and skills expected at each tested grade level" (Zyskowski, 2008, p. 3). The Spring 2009 Grade 3 and Grade 4 Mathematics TAKS Tests were considered reliable according to the TEA (2009a). Evidence for validity of these TAKS

Tests was based on test content, the response process, the internal structure of the test, relationships with other variables, and test consequences (TEA, 2009c).

Assumptions

The researcher made certain assumptions about this study.

- A two-way dual language immersion program is one type of bilingual educational program, so the researcher assumed that students in this type of program could be referred to as bilingual students.
- The researcher also assumed that the reader would understand that the students who are referred to as participating in a monolingual English program receive instruction in a monolingual setting even though some of the students may be bilingual.
- The researcher assumed that pertinent, reliable, and valid data were obtained from the Mathematics TAKS Test for each group of students.
- An assumption that the Mathematics TAKS Test provided accurate measures to answer the research questions was also made based on KR20 reliability estimates provided by the TEA (2009c).
- The researcher assumed that the TEA sent complete and accurate data.
- The researcher also assumed that the populations for the study were normally distributed. Even if this assumption was violated, Pallant

(2007) declares that a violation of this assumption with most parametric techniques should not cause a major problem with sample sizes of 30 or more.

- The researcher assumed that an alpha of .05 was an appropriate level to prevent a Type I error and that the sample sizes were large enough to prevent a Type II error.

Definitions

Bilingual Educational Program

A *bilingual educational program* includes the use of two languages in a classroom for instruction (National Association for Bilingual Education, 2009). Numerous program models exist based on the program's methods and goals, and these include transitional, developmental, and two-way bilingual education (National Association for Bilingual Education, 2009). Thus, a two-way dual language immersion program is one type of bilingual educational program. Table 1 shows the types of educational programs based on language that are offered in the state of Texas according to the bilingual indicator coding or the TAKS Test (TEA, 2009h).

Table 1
Types of Educational Programs Based on Language that are Offered in the State of Texas According to the TAKS Test Bilingual Indicator Coding

Educational Programs	
Bilingual	Monolingual
• Transitional Bilingual/Early Exit • Transitional Bilingual/Late Exit • Dual language immersion/two-way • Dual language immersion/one-way	• Student is not participating in a state-approved full bilingual program

Note. The programs are based on the descriptions provided as bilingual indicator codes (TEA, 2009h).

Criterion-Referenced Test

A *criterion-referenced test* makes a comparison of a student's performance with objectives, skills, and knowledge areas that have been clearly defined prior to the test (Dow, 2008). The Mathematics TAKS Test is considered a criterion-referenced test since it is based on TEKS Objectives.

Language-Majority Students

Language-majority students speak the primary language of the region. These are the English-speaking students in the United States (Center for Applied Linguistics, 1993). These are the native English-speaking students in a two-way dual language immersion program in the United States.

Language-Minority Students

Language-minority students do not speak the primary language of the region. In the United States, these are the students who do not speak English in the home (Center for Applied Linguistics, 1993). These are the native Spanish-speaking students in a two-way dual language immersion program teaching a second language of Spanish in the United States.

Mathematical Proficiency

The NRC (2001) defines *mathematical proficiency* as the intertwining of five key strands including conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. More specifically:

- Conceptual understanding centers on a comprehension of mathematical ideas including concepts, operations, and relations in an integrated functional way (NRC, 2001).
- Procedural fluency focuses on acquiring, selecting, and demonstrating mathematical skills and actions with accuracy and efficiency (NRC, 2001).
- Strategic competence includes the capacity to develop a plan for solving mathematical problems including representations and formulations as necessary (NRC, 2001).
- Adaptive reasoning includes the ability to use logic in thinking while reflecting on and providing justification for mathematical situations with an understanding of conceptual relationships (NRC, 2001).
- Productive disposition refers to the tendency to view mathematics as valuable while also believing in one's own ability in mathematics (NRC, 2001).

Monolingual English Program

In a monolingual English program in American schools, the English language is used as the language of instruction. Modifications are made for special education students, and strategies for teaching English as a second language are integrated into instruction. Students in a monolingual English program are coded as a "0" for the bilingual indicator code on the TAKS Test, and this coding represents that these students are not "…participating in a state-approved full bilingual program" (TEA, 2009h, p. 5).

One-way Spanish Language Immersion Program

In a *one-way Spanish language immersion program* in American schools, almost all of the students speak English and are learning the second language of Spanish (Center for Advanced Research on Language Acquisition, 2009).

Scaled Score

A *scaled score* on the Mathematics TAKS Test is "… a conversion of the raw score onto a 'scale' that is common to all test forms for that assessment" (TEA, 2009b, p. 52). A scaled score results from placing different tests with different numbers of test items onto a common scale in order to "… allow direct comparisons of student performance across separate test forms and different test administrations" (TEA, 2009b, p. 52).

Two-Way Dual Language Immersion Program

A *two-way dual language immersion program* contains an educational environment where students are exposed to academic instruction in two languages with native English speakers and native speakers of the other language integrated for instruction (Center for Applied Linguistics, 2010b). The alternation of language of instruction varies and can include transitions by week, day, or half day (Gómez et al., 2005).

Visual Prompt

A question with a *visual prompt* (or simply *visual*) is defined as any question containing a picture, table, graph, or manipulative associated with the problem. Questions with boxes or drawn out spaces as part of a problem are considered visuals as well, unless the box is only representative of the result of a numerical expression as part of the answer choices. Numerical symbols are not considered visual prompts. Various categories of questions with visual prompts are used in this study.

- If a question contains any type of graph such as a pictograph or line graph, the question is included in the category for graphs.
- If a question contains any type of table with columns to organize information, the question is included in the category of tables.
- If the question contains any type of geometric figure such as an image of a two-dimensional figure or three-dimensional solid, the question is included in the category of geometric figures.
- If the question contains a visual image such as pieces of money or a clock that the student could use as a manipulative, the question is included in the category of manipulatives. Questions that include basic visual images of objects are also included in this category if details on the visual image could actually be counted as a manipulation by the student.

- If the question contains a visual that is based on a pattern, the question is included in the category of patterns.

Organization of Chapters

This research study examined the effects of a two-way dual language immersion environment on elementary mathematics TAKS Test scores of third- and fourth-grade students in Texas. More specifically, scores for students enrolled in a two-way dual language immersion program were compared to scores for students who were enrolled in a monolingual education program, and percentages of correct responses on subsets of questions on the Mathematics TAKS Test with a visual prompt were compared to percentage of correct responses on a set of questions without a visual prompt.

The study is organized into five chapters. Chapter I is titled "An Introduction" and includes a rationale for the study, the statement of the problem, purposes of the study, research questions, limitations and delimitations of the study, instrumentation, assumptions, and definitions. Chapter II is titled "A Review of Related Literature" and includes the changing population of students in American schools, a focus on two-way dual language immersion programs, previous studies focused on mathematics achievement in relation to language, previous studies focused on bilingual education, the learning environment in a two-way dual language immersion program, teaching strategies and behaviors that include visuals, and the use of visual prompts in learning mathematics. Chapter III is titled "Design of the Study" and includes a description of the theoretical framework used for the research, a description of Mathematics TAKS

Test scores, a description of the data used in analysis, instrumentation, the analytic framework, and the analytic process. Chapter IV is titled "Presentation and Analysis of Data" and includes data separated by grade level (third or fourth) and also separated by test version (English or Spanish). The groups included two-way dual language students and students in a monolingual English program. Data focused on overall scaled scores on the entire test, overall correct responses on various subsets of questions with a visual prompt, and overall correct responses on questions without a visual prompt. Overall scaled scores were analyzed using a one-way between groups ANOVA, and multiple one-way between groups ANOVAs were used to analyze the performance of two-way dual language immersion students compared to students in a monolingual English program on nonvisual questions compared to various categories of visual questions on the Mathematics TAKS Test. Multiple one-way ANOVAs were conducted to analyze the effect of question type on Mathematics TAKS Test performance for students in a two-way dual language immersion program as well as for students in a monolingual English program. A 2x2 Mixed Between-Within ANOVA with factors of question type (visual and nonvisual) and educational program (two-way dual language and monolingual education) was used to analyze the data for an interaction and main effects. Chapter V is titled "Conclusions and Implications" and includes a summary of the overall study, a summary of the findings that are detailed in Chapter IV, conclusions based on the findings, a discussion related to the findings, implications and recommendations for theory and practice, and limitations and recommendations for future research. A list of all references follows the five chapters.

CHAPTER II

A REVIEW OF RELATED LITERATURE

Introduction

In order to situate this study into existent knowledge and findings, a review of literature had to first be conducted. This review began with a presentation of analyses centered on the changing population of students in American schools. Secondly, the researcher focused on current models of two-way dual language immersion programs and statistics related to the students who participate in these types of educational programs. Next, the researcher presented results of previous studies focused on mathematics achievement in relation to language. Then results of previous studies focused on bilingual education were presented. Finally, the researcher focused on the actual learning environment in a two-way dual language immersion program, teaching strategies and behaviors that include visuals, and the use of visual prompts in mathematics instruction.

Changing Population of Students in American Schools

Educational environments for mathematics instruction are evolving with the ongoing changes in the population of students in public schools across America. *The Condition of Education 2009* indicates an increase in diversity of public schools, including Hispanic students, who account for 21% of the rising enrollment in public schools across America (Planty et al., 2009). From 1972 to 2007, the enrollment of

Hispanic students in public schools rose from 6% to 21% of the academic population while the enrollment of Caucasian students in public schools decreased from 78% to 56% of the academic population during this same time period (Planty et al., 2009). Specifically in the southern region of the United States, the enrollment of Hispanic students in public schools rose from 5% to 19% of the academic population between 1972 and 2007 while the enrollment of Caucasian students in public schools decreased from 70% to 51% of the academic population during this same time period (Planty et al., 2009). *The Condition of Education 2009* also indicates an increase from 9% to 20% of the academic population between 1979 and 2007 for children 5-17 years old who spoke a language other than English at home (Planty et al., 2009). Out of the 10.8 million children who spoke a language other than English, 7.8 million (72%) spoke Spanish (Livingston, 2008).

Hussar and Bailey (2008) project a 12% increase in the number of children enrolled in prekindergarten through grade 8 from 2005-2017. The projected increase in public elementary and secondary schools in the United States from 2005-2017 is 10% overall with the state of Texas projected to be at 32.9% (Hussar & Bailey, 2008). With these projections of growth, the rising enrollment of Hispanic students, and the large number of children who speak Spanish at home, alternate instructional approaches are evolving. One approach includes a two-way dual language immersion program in which both native English-speaking students and native Spanish-speaking students are immersed in both the English and Spanish language and culture during the elementary school years, with an ultimate goal of all students becoming bilingual and culturally diverse.

A Focus on Two-Way Dual Language Immersion Programs

Models of a two-way dual language immersion program include both a 90-10 model and a 50-50 model. In the 90-10 model, approximately 90% of instruction in early grade levels is provided in the minority language with increasing levels of English until equality in the use of both languages is reached, as early as the fourth grade (Howard et al., 2003). In the 50-50 model, instruction occurs in equal amounts for both languages (Howard et al., 2003). The alternation of language of instruction in the 50-50 model varies and can include transitions by week, day, or half day (Gómez et al., 2005). "Programs vary in terms of the amount of time they devote to each language, which grade levels they serve, how much structure they impose for the division of language and curriculum, and the populations which they serve" (Garcia & Jensen, 2006, p. 2). One study describes a two-way dual language immersion program where mixed groups of native English- and Spanish-speaking students rotated on a weekly basis between two different teams of teachers (Barnett et al., 2007). During one week, the team of English teachers taught one group of students in English while the team of Spanish teachers taught the other group in Spanish (Barnett et al., 2007). Mathematics instruction varies within different programs, with some offering mathematics instruction in only one of the two languages that are included in the program and others offering mathematics instruction in both languages (Gómez et al., 2005).

Students in a two-way dual language immersion program live in homes that are either English dominant, dominant in the second language, or bilingual. In a recent study of 724 families involved in a dual language program in New Mexico, 40.5% of the parents were reported to be bilingual in Spanish and English (Parkes, 2008). Since a student must learn two different languages in a two-way dual language immersion program, the students whose parents are bilingual may have educational advantages within the home over the students of monolingual parents. Bilingual parents can converse in both languages with the students and assist the students with difficulties that may arise in either language. While monolingual parents can assist their children in the dominant language, students with monolingual parents do not receive instruction equivalent to those with bilingual parents.

Research literature has indicated cognitive advantages for students who reach a certain level of competence in their two languages (Cummins, 1979). Students immersed in a dual language immersion program who do not reach the level of balanced proficiency become cognitively disadvantaged not only when compared to the other students in the program who become proficient in the two languages, but also to the monolingual students who are not enrolled in a dual language immersion program (Garcia, 1986). Thus, some may criticize educators in an early elementary dual language immersion program as taking a gamble that the children will become proficiently balanced and have all the advantages of other students. Bilingual parents can often help their children at home to reach the level of balanced proficiency, but the monolingual parents depend on the school, for the most part.

In order to develop an educational program that attempts to satisfy parents, educators must have an understanding of reasons parents choose a two-way dual language immersion educational environment for their children. Research literature focused on how and why parents choose to enroll a child in a bilingual education program such as a two-way dual language program is complex because very few studies include the broader focus on language acquisition and enrichment (Parkes, 2008). One particular study focused on dual language programs analyzed why families chose such a program. The most popular response in this study included the ability to speak, read, and write in two languages, with 93.6% selecting this reason (Parkes, 2008). Other popular reasons included the desire to be successful in a global society (63.1%), the desire to achieve more success in school (61.3%), and the desire to be comfortable in relating to different people and cultures (60.7%) (Parkes, 2008). When this data was broken down based on parents who were English dominant, Spanish dominant, and bilingual, 87.6% of the English-dominant parents chose being able to speak, read, and write in two languages as the reason for enrolling their children in the program (Parkes, 2008). From this same group of parents, 60.33% of the English-dominant parents selected comfort in relating to different people and cultures, 60.33% selected being successful in a global society, 56.2% chose being more successful in school, and 52.07% chose being better able to relate to his/her heritage as reasons for enrolling their children in the program (Parkes, 2008).

The involvement of parents in the education of their child is important when enrolling a student in a two-way dual language immersion program. In a study focused on the involvement of 14 Spanish-speaking parents and 13 English-speaking parents in a two-way bilingual school program, the researcher concluded that "parents' comfort with the staff and the school was a critical first step that led to their involvement" at the school (Zelazo, 1995, p. 3). "Language played a major role in how parents were involved at the school" (Zelazo, 1995, p. 4). Since most of the structural organization of the school was centered around the English language, the research confirmed that more English-speaking parents were involved (Zelazo, 1995). Howard et al. (2003) reported that both students and parents had positive attitudes toward two-way dual language immersion programs and that students had developed positive attitudes toward being bilingual and multicultural. The important roles of the parents of immigrant children in second-language acquisition was referenced in one study based on the idea that the first-language is used as the foundation for learning the second language (Berryman, 1983, as cited in Shin, 2000).

Parent views are also important in a two-way dual language immersion program. An analysis of what parents think about two-way bilingual educational programs was conducted with 366 parents who completed a survey (Ramos, 2007). On the section related to the parents' satisfaction with the program, 82.2% of the parents strongly agreed that their children are given access to subject matter, and 87.4% would recommend the program to others (Ramos, 2007). In the statement focused on whether the program does not develop the ability to communicate in Spanish, 12% indicated that they strongly agree, and 7.4% were unsure (Ramos, 2007). Participants expressed that the program does develop the ability to read in English (83.1% strongly agreed), and only 14.2% strongly agreed that the program does not develop the ability to write in English, with 11.7% unsure (Ramos, 2007). Of those surveyed, 89.1% strongly agreed that they possess the language skills needed to help their child with homework, while 90.2% strongly agreed that they possess the academic skills to help with homework (Ramos, 2007). In the focus on parental support for Spanish, 63.1% read with their child in Spanish at least 1 to 2 times each week, 26.2% checked out or bought books in Spanish at least 1 to 2 times each week, 62.8% invited home Spanish-speaking friends at least 1 to 2 times each week, and 60.1% visited Spanish-speaking children at least 1 to 2 times each week outside of school (Ramos, 2007). Ramos reported that "…more than 84% of the parents facilitated their children's periodic encounters with Spanish-speaking friends in an effort to promote and develop their children's Spanish skills" (2007, p. 146). In a study focused on a two-way dual language immersion school in Chicago, 200 parents were surveyed with 20 items (Saucedo, 1997). Over 90% of the survey participants were satisfied with the program and would recommend it to others, while 97% of the participants perceived learning a second language as important (Saucedo, 1997). This particular research study commented that

> Educating a child is a shared responsibility between the school, community and parents. Together they form an integrative and instrumental team directly involved in addressing the academic and socio-cultural needs of the child so as to prepare them to become viable citizens that can effectively function in our increasingly multicultural and multilingual society. (Saucedo, 1997, p. 5)

Results of the study indicated that 97% were satisfied with their children's second language development while 95% were satisfied with their native language development (Saucedo, 1997). Results also indicated that 98% agreed that the dual language immersion program enhanced cross-cultural attitudes and appreciation (Saucedo, 1997).

Very little research exists with a focus on instructional design in a dual language immersion program. With the rapid growth of this type of educational program, an early elementary two-way dual language immersion program fosters potential problems for teachers and administrators who must develop and implement an instructional design for the benefit of all students in the program.

Previous Studies Focused on Mathematics Achievement in Relation to Language

Reading and mathematics proficiency for Hispanic students lag behind that of others (Snyder, 2009). For two-way dual language immersion programs that use English as the primary language of instruction in mathematics, this issue compounds for Hispanic students. Reading scores on the National Assessment of Educational Progress (NAEP) for eighth graders in 2007 included an average scaled score of 263 (Snyder, 2009). The scaled score for Hispanic students in reading fell below average at 247 (Snyder, 2009). "Development of literacy in a second language appears to occur more slowly if the student's first language literacy is weak or nonexistent" (Christian, Montone, Carranza, Lindholm, & Proctor, 1996, p. 2). Reading proficiency can directly affect problem solving in mathematics, so the issue of lower scores by Hispanic students fosters concern for mathematics achievement. Mathematics scores on the NAEP for eighth graders in 2007 included an average scaled score of 281 (Snyder, 2009). The scaled score for Hispanic students fell below average at 265 (Snyder, 2009).

According to the National Council of Teachers of Mathematics [NCTM], equity provides excellence in mathematics education by allowing the learning potential for all learners to be maximized (2009). This idea of equity can be generalized to all academic areas. Teachers must establish equity in their practices and encourage students to value and respect each other's work while trying to build a positive environment related to cultural roots and history for all students (NCTM, 2009). Thus, a dual language program offers a possible solution for increasing the academic proficiency of Hispanic students by offering a culturally responsive learning environment. The cultural diversity of all students must be accepted in the classroom, while teachers maintain a clear understanding of the role of a student's first language in learning (NCTM, 2008). The importance of communication in the classroom signifies that teachers must incorporate instructional strategies to assist students in accessing content in a second language (NCTM, 2008).

Recent dissertation studies focused on elementary students in immersion programs indicate higher mathematics scores for immersion students compared to students not enrolled in an immersion program (Dow, 2008; Egan, 2007). In a quantitative research study focused on test results on a state standardized test for second and third-grade elementary students in a one-way Spanish language immersion program in Arizona, the mathematics scores of the students in the immersion program were significantly higher than the scores of students who were at the same school but not in the program (Egan, 2007). A longitudinal study covering a six-year period focused on both norm-referenced and criterion-referenced test results for elementary English learners in one-way and two-way bilingual education programs in El Paso, Texas (Dow, 2008). The study reported that students from the two-way program were performing higher in mathematics (Dow, 2008).

Language fluency can contribute to academic performance and can directly affect problem solving in mathematics. Perie et al. (2000) stated that non-English speaking students in the United States exhibit lower academic performance. A lower proficiency of language may possibly result in the lower academic performance. The importance of communication in the mathematics classroom signifies that teachers must incorporate instructional strategies to assist students in accessing content in a second language (NCTM, 2008). Mathematics centers on an academic field with its own specialized language (NCTM, 2008), so students in a two-way dual language immersion program must really focus on the understanding and fluency of three languages. According to Vygotsky,

> a foreign language facilitates mastering the higher forms of the native language. The child learns to see his language as one particular system among many, to view its phenomena under more general categories, and this leads to awareness of his linguistic operations. (1962, p. 110)

Thus, the exposure to varied languages can possibly increase language fluency based on Vygotsky's ideas and possibly offer a direct effect on the ability to solve problems in mathematics.

Studies Focused on Bilingual Education

Research focused on the effects of bilingual education has been an interest for over 20 years, with positive effects of bilingual education being shown. Cziko (1992) viewed bilingual immersion programs as being a fairly new type of educational program at that time. Medrano (1988) reported a study in which mathematics test results from first- and third-grade students in a Texas school indicated that a bilingual educational program positively affected mathematical posttest scores for learners. This same study also reported, at a 99% confidence level, that students in the bilingual educational program had higher scores than those students who were not in the bilingual educational program (Medrano, 1988).

Other studies support a trend of high academic achievement levels in bilingual educational environments (Lambert et al., 1993; Lindholm & Fairchild, 1988). Lindholm and Fairchild (1988) reported language-majority and language-minority students to be above grade level in mathematics in a San Diego bilingual immersion program. Cziko stated that this San Diego program "… shows it is possible for both Hispanic and Anglo students to attain levels of academic achievement at or above national norms in two languages and in a fully integrated classroom" (1992, p. 15). Lambert et al. (1993) reported that bilingual education learners in a French and English program scored much higher on a mathematics test involving conceptual and computational knowledge than the monolingual control groups. Researchers equated groups in the study according to overall intellectual ability, comparable social class backgrounds, and comparable time in respective programs (Lambert et al., 1993). They identified this differential in scores to be related to knowledge transfer. "Clearly some very effective form of conceptual transfer, from the second to the first language, transpires for these students, since the math concepts and procedures learned through French are apparently fully accessible through tests given in English" (Lambert et al., p. 18).

The Learning Environment in a Two-Way Dual Language Immersion Program

Potowski (2007) describes a model of dual language immersion classrooms that involves both English and a non-English language.

> Dual immersion classrooms contain a mixture of English-speaking and native-speaking children of the non-English language. In other words, at all times, part of the class is immersed in its L2 [second language] and the other half receives instruction in its L1 [first language], giving rise to the program descriptor term 'two-way' or 'dual' immersion. (Potowski, 2007, p. 9)

Two major reasons for helping students to become bilingual include the academic achievements that can be reached through a bilingual education and the ongoing changes in the demographics within the United States that affect the outlook on jobs (Linholm-Leary, 2005). The learning environment in a two-way dual language immersion program involves the use of a non-English language at least half of the time, the use of only one language for certain parts of the instructional day, participation by both English and non-English speakers preferably in equal numbers, and the integration of students for instruction of all content (Lindholm, 1987). Lindholm-Leary (2005) cited the need for high-quality teachers in the development of establishing effective dual language environments. The need for parents from all linguistic and cultural backgrounds to feel welcomed and valued is an integral part of the dual language immersion program (Lindholm-Leary, 2005).

Visuals provide one aspect of a two-way dual language immersion environment for students learning a second language. Beginning language learners "… need a tremendous amount of visual and contextual support" (Coelho, 2004, p. 17). Thus, visuals arise as an integral part of a two-way dual language immersion environment.

In a study of 182 schools in 19 states that offer two-way bilingual educational programs, differences existed in the ratio of instructional time in each language (Christian et al., 1996). Data was solicited from two-way programs, and 35 different programs with minimum levels of instruction in the non-English language and student integration were included for data analysis (Christian et al., 1996). Overall, dual language students as a whole were outperforming students in non-two-way programs with more advanced Spanish language skills as either a first or second language and are comparable to speakers of their second language (Christian et al., 1996). Howard et al. (2003) argued that students in bilingual programs develop academic skills that are equal or above those of their peers in English-only environments. Linholm-Leary (2005) reported that the students with higher levels of bilingualism achieve at higher academic and cognitive levels than students in monolingual programs or those who have poor bilingual skills.

Certain classroom conditions were presented as supporting the learning for English students (WestEd, 2004), but these ideas can also be extended and viewed as supportive for Spanish learners in a two-way dual language immersion program. Teachers presented curriculum at increasingly higher levels with interrelatedness as opposed to simply developing a linear progression of concepts (WestEd, 2004). Another supportive approach included the use of instructional scaffolding such as modeling, bridging, contextualization, schema building, text re-presentation, and metacognitive development (WestEd, 2004).

Teaching Strategies and Behaviors That Include Visuals

The use of visuals during instruction evolved as a central phenomenon in a research study performed in a two-way dual language immersion program in Texas (Beck & Cifuentes, 2010). The visual intervention strategies that appeared most often from interviews and repeated teacher observations included:

- the use of labels in the classroom;
- the use of manipulatives as a visual aid;
- the use of gestures/modeling;
- the use of pictures of vocabulary and concepts;
- and the construction of tables, graphs, charts, and diagrams (Beck & Cifuentes, 2010).

Mathes et al. (2007) list the use of concrete gestures and visuals as one of many teaching techniques in working with students learning English as a second language. In their study, which focused on teaching native Spanish speakers struggling with reading in English, the researchers stated that "In addition to providing a definition orally, pictures, gestures, and role play were used to enhance the students' understanding of various words" (Mathes et al., 2007, p. 267).

Akbulut (2007) studied sixty-nine students who were learning English as a foreign language. Students were randomly assigned to three groups: one exposed to definitions of words, one to definitions and pictures of words, and one to definitions with short videos associated to the word. The researcher concluded that the "…groups that had access to definitions with both types of visuals had significantly higher vocabulary scores on both immediate and delayed posttests than the definition only group" (2007, p. 499).

The Use of Visual Prompts in Learning Mathematics

Verbal instruction allows a student to hear but not necessarily listen. Visual instruction alone allows a student to see but not necessarily focus. The use of visual prompts with verbal instruction encourages students to search for and hopefully gain a deeper conceptual understanding and build representations in their minds to connect to future problem-solving endeavors.

Teachers who utilize visual prompts during mathematics instruction attempt to enhance learning by offering visual support to the auditory instruction that occurs during a lesson. Visuals can be used to deploy attention during problem-solving lessons in mathematics. "If novel stimuli, such as graphics or video, are used to present the problem, learners are likely to be more interested" (Smith & Ragan, 2005, p. 223). Evidence for the importance of the inclusion of visuals became apparent in the examination of documents related to mathematics education from various national and state agencies. The NRC discusses the inclusion of visual instructional materials to help children learn mathematics through the representation of numbers (2001). The NCTM emphasizes the use of technology to provide visual images of mathematical ideas (2000). Representations can consist of visuals such as drawings, diagrams, gestures, and symbols, and the NCTM stresses the importance of students being able to use multiple representations in the organization and communication of mathematical ideas (2000). From as early as kindergarten, students are expected to "communicate mathematical ideas using objects, words, pictures, numbers, and technology" (TEA, 1998, §111.12. Mathematics, Kindergarten, (b) Knowledge and Skills (14)(A)). This focus on the use of various types of visuals appears throughout all elementary grade levels as part of the Texas Essential Knowledge and Skills for Mathematics (TEKS) (TEA, 1998). *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics* includes the use of visual models and visual tools in the representation and solution of problems (NCTM, 2006).

A Description of How Students Learn

In order to gain an understanding of how the use of visual prompts may affect learning in mathematics, a description of how students learn needs to first be understood. Smith and Ragan (2005) provided a description based on what psychologists believe happens cognitively at conscious or unconscious levels while students are learning.

> First, students are immersed in a plethora of sensory inputs – sounds, sights, tactile stimuli, odors, and tastes. For learning to occur, students must choose to attend to those stimuli in the learning environment that are related to the learning task and instruction and to ignore competing stimuli, such as the band practicing outside nearby. This process is called *selective perception*. Following perception, information is momentarily stored in working memory. Next, students 'take in' the information in the instruction, using things they already know to help them understand the new information. They interpret this new information based on the related content knowledge, values, beliefs, and strategies that they already have available in long-term memory. During this process of relating what they already know to what is new, much of the new information is stored (encoded) into long-term memory, adding to or modifying what students already know. Either immediately or later, students may retrieve from memory their new learning to answer questions, solve problems, or understand yet more new information. (Smith & Ragan, 2005, p. 129)

Using Visuals as an Instructional Tool

The NRC (2000) describes how visual information helps organize brain development.

> The brain development process actually uses visual information entering from outside to become more precisely organized than it could with intrinsic molecular mechanisms alone. This external information is even more important for later cognitive development. The more a person interacts with the world, the more a

person needs information from the world incorporated into the brain structures. (NRC, 2000, p. 118)

Research provides evidence advocating for the use of visuals as an instructional tool. Lowrie and Kay (2001) declared that "… students may find it easier to acquire schemas associated with diagrams, rather than with words, because the cognitive load associated with diagrams may place less burden on working memory" (2001, p. 249). Ainsworth et al. (2002) discussed how multiple external representations (MERs) are used to support learning in a traditional educational environment. "For example, percentages and fractions such as 33% or 1/3 are often presented to children alongside a drawing of a pie chart with one third shaded" (Ainsworth et al., 2002, p. 26). Nontraditional learning environments also benefited from the use of visuals. For example, visuals provided one aspect of a dual language immersion environment for students learning a second language. Beginning language learners "… need a tremendous amount of visual and contextual support" (Coelho, 2004, p. 17). "Interactions with external imagistic representations are important to facilitating the construction of powerful internal imagistic systems in students," and this "… internal, imagistic representation is essential to virtually all mathematical insight and understanding" (Goldin & Kaput, 1996, p. 415). These external imagistic representations included visual prompts such as graphs and pictures (Goldin & Kaput, 1996), so the inclusion of visual prompts in mathematics instruction surfaced as an important component in reaching mathematical insight and understanding.

Seng and Chan (2000) argued that the mathematics curriculum should include spatial thinking skills to overcome deficiencies in spatial ability and visual literacy. They discussed how teachers use visual representations in the form of diagrams, pictures, charts, tables, and graphs during mathematics instruction to assist in understanding concepts and ideas of the lesson. "Teachers' gestures have the potential to serve a crucial role in building bridges between words and external representations" (Flevares & Perry, 2001, p. 332). In a longitudinal study of three first grade teachers, between 5.07 and 7.13 different nonspoken representations were used during each minute of instruction (Flevares & Perry, 2001). This frequent use of nonspoken representations in these particular first grade classrooms illustrated that visual prompts are being incorporated into classroom instruction as the teachers strive to help students make connections between spoken words and external representations in the form of visual prompts.

Hegarty and Kozhevnikov (1999) and van Garderen (2006) distinguished between two different types of visual representations used to solve problems in mathematics. These included "… schematic representations that encode the spatial relations described in a problem and pictorial representations that encode the visual appearance of the objects described in the problem" (Hegarty & Kozhevnikov, 1999, p. 684). A distinction between visual imagery and spatial imagery was made by van Garderen (2006). "*Visual imagery* refers to the representation of the visual appearance of an object, such as its shape, color, or brightness, whereas *spatial imagery* refers to the representation of the spatial relationships between the parts of an object and the location of objects in space or their movement" (van Garderen, 2006, p. 497). The use of visual imagery in the mathematics classroom could include visual prompts such as objects that students can use to practice measurement, attribute manipulatives that students can use to sort by color and shape, or pictures of various geometrical shapes such as rectangles and triangles. The use of spatial imagery in the mathematics classroom could include visual prompts such as a number line graph or rectangular coordinate system where points can be plotted or distances can be counted, a two dimensional net that can be folded to form a three dimensional solid, or a clock that can be manipulated to show current or elapsed time.

Owens and Clements discussed a problem solving model that focuses on "… the role of visual imagery in establishing the meaning of the problem, in channeling the problem-solving approaches of the students, and in influencing students' cognitive constructions" (1998, p. 216). When a visual is used during mathematics instruction, researchers can speculate how the visual will assist the student to establish meaning, channel an approach for a future solution of a mathematics problem, and influence a student's cognitive construction as described by Owens and Clements (1998). The visual serves to help the students make connections to concepts and provides visual images that hopefully can be recalled in the future during problem solving. Smith and Ragan (2005) elaborated on how visuals can be used as part of associational and organizational techniques to assist in the processing of information for declarative knowledge and concept learning. More specifically, visuals allow students to learn labels, names, facts, and lists (Smith & Ragan, 2005). Another example included how visuals can be used to assist students in isolating attributes while learning concepts (Smith & Ragan, 2005). "Children establish meaning by responding to a given stimulus or situation and linking their existing concepts and images with the situation" (Owens & Clemens, 1998, p. 201).

A particular type of visual prompt that can be used during mathematics instruction to help students organize information includes a diagram. Diezmann and English defined a diagram as "… a visual representation that displays information in a spatial layout" (2001, p. 77). They discussed how a diagram can help a student analyze the structure of a problem to plan an approach for finding a solution (Diezmann & English, 2001). Teachers must help students learn how to effectively use a diagram as a mathematical tool (Diezmann & English, 2001). Larkin and Simon (1987) offered reasons for a diagram being superior to a verbal description when solving problems. One particular reason focused on the idea that "… diagrams automatically support a large number of perceptual inferences, which are extremely easy for humans" (Larkin & Simon, 1987, p. 98). However, they warned that diagrams only benefit those who understand the appropriate computational processes related to the diagram (Larkin & Simon, 1987). Thus, while diagrams may be provided during mathematics instruction, only students who understand the mathematical process associated with the diagram will benefit. Teachers must assist in this understanding of the underlying mathematical process.

A focus on representation as one of the Process Standards presented in the *Principles and Standards for School Mathematics* emphasized the importance of visuals as supporting mathematics instruction with a focus on how these visuals should be included.

> Some forms of representation – such as diagrams, graphical displays, and symbolic expressions – have long been part of school mathematics. Unfortunately, these representations and others have often been taught and learned as if they were ends in themselves. Representations should be treated as essential elements in supporting students' understanding of mathematical concepts and relationships; in communicating mathematical approaches, arguments, and understandings to one's self and to others; in recognizing connections among related mathematical concepts; and in applying mathematics to realistic problem situations through modeling. (NCTM, 2000, p. 67)

Another important reason for including visuals during mathematics instruction centers on the inclusion of visual prompts on standardized tests that students may be required to complete for assessment purposes. Matteson (2006) identified and analyzed representations used to present algebra problems from the 2003 and 2004 Texas Assessment of Knowledge and Skills (TAKS) tests for Grades 3 through 8. "The ability to interpret and analyze representations is predominate in standardized mathematical assessments" (Matteson, 2006, p. 208). Educators must provide students with opportunities to work with a variety of representations to build mathematical literacy and prepare students for standardized assessments (Matteson, 2006). In the research study that categorized the algebraic questions on the TAKS tests for Grades 3 through 8, the graphical representation category included pictorial items, visual items used for modeling, horizontal and vertical charts, and various types of graphs (Matteson, 2006). Based on the categorization of questions identified in the study, the percentages of graphical representations used to present the algebra problems at each grade level included: Grade 3, 41.7%; Grade 4, 7.1%; Grade 5, 0%; Grade 6, 22.2%; Grade 7, 30%; and Grade 8, 20% (Matteson, 2006).

Student Responses to Visuals

When mathematics instruction and problems are presented with visuals, students respond in various ways. Shama and Dreyfus argued that "… students appear to tend towards the use of visual strategies for solving problems that are presented in a visual setting" (1994, p. 62). Shama and Dreyfus (1994) believed that the use of visual settings during situations where students are solving problems can improve visual reasoning skills of students. However, Ainsworth et al. (2002) argued that learners will not benefit from the use of external representations such as visuals if they are unable to translate or map knowledge from one representation to another. Thus, teachers must utilize visuals during instruction and assist students in learning how to use visual strategies with an appropriate transfer of knowledge. The more opportunities teachers provide for students through the use of visual prompts during mathematics instruction, the more efficient students will become in utilizing the visuals while solving problems.

One study suggested that students who have a low spatial visualization ability display preference in using pictorial images while students with a higher spatial visualization ability display preference in using schematic imagery in the solution process of mathematical word problems (van Garderen, 2006). Pictorial representations only focus on an object's appearance, so these are considered at a lower level since the schematic representations include actual spatial relations of an object included in the problem. Lowrie & Kay (2001) argued that the difficulty of the problem determines the representation chosen by a student with visual methods being used more often to complete problems that are viewed as difficult.

The Effects of Visuals on Mathematics Achievement

"Visual skills appear to have an important role in mathematics performance" (Seng & Chan, 2000, p. 6). Visuals are used in the presentation of basic concepts in mathematics, especially in the lower grade levels of elementary school (Seng & Chan, 2000). Students must have spatial ability to understand and not hinder the presentation of these basic mathematical ideas (Seng & Chan, 2000). Students use diagrams and visual images combined with verbal definitions and analyses to construct concepts (Seng & Chan, 2000).

In two different studies, results indicated that the use of schematic representations had a positive correlation to a higher performance in solving mathematics problems while the use of pictorial representations had a negative correlation (Hegarty & Kozhevnikov, 1999; van Garderen, 2006; Edens & Potter, 2008). Seng and Chan (2000) also found a positive relationship between the spatial ability of elementary students and mathematical performance. Various items on the tests used in the study contained visual representations (Seng & Chan, 2000). "One explanation for the positive relationship lies in the manner in which mathematics ideas are acquired. If visual representations were used during mathematics instruction, the students' spatial ability can have a strong influence on mathematical understanding" (Seng & Chan, 2000, p. 6).

One comparative case study identified how visual-spatial instructional strategies affected student achievement for those identified as visual-spatial learners in the elementary classroom (Dean, 2007). The experimental group received mathematics instruction through the use of games and manipulatives while the control group received traditional instruction through the use of a textbook (Dean, 2007). This particular research study found no significant differences between the two groups in mathematics achievement (Dean, 2007).

In a study focused on children with attention deficit/hyperactivity disorder, researchers analyzed how visual stimulation affects the mathematics performance of these children (Lee & Zentall, 2002). Visual stimulation included the use of colored screens, colored numbers, and movement effects with transition from one screen to another (Lee & Zentall, 2002). Students in the experimental group that included these types of visual stimulation completed more problems and completed more problems correctly on the computerized mathematics test used in the study than students in the control group who did not receive the visual stimulation (Lee & Zentall, 2002).

Conclusion

The increasing enrollment of Hispanic students in public schools across America creates a rising need for alternate educational programs such as a two-way dual language immersion program (Planty et al., 2009). While program models, family support for the program, family views of the program, and family involvement in the program vary, previous studies that have focused on mathematics instruction in bilingual programs mostly show advantages for students in the programs (Dow, 2008; Egan, 2007; Lambert et al., 1993). The learning environment in a two-way dual language immersion program includes the use of visual prompts as an integral part of mathematics instruction (Beck & Cifuentes, 2010). Evidence for the importance of visuals becomes apparent as researchers reveal positive correlations in mathematical performance based on the use of certain visuals (Finnan-Jones, 2007; Lee & Zentall, 2002; Seng & Chan, 2000). State and national agencies discuss the need for the inclusion of visuals in the mathematics curriculum to provide visual images for various mathematical ideas (NCTM, 2000, 2006; NRC, 2000, 2001; TEA, 1998).

CHAPTER III

DESIGN OF THE STUDY

Theoretical Framework Used for Research

A quasi-experimental design with static-group comparison was used for the purposes of this study. While the inability to randomly assign students to groups was an obvious weakness of the study, students were already participating in selected programs by the chosen grade levels. Data were collected from the TEA for students who were enrolled in a two-way dual language immersion program or who were not participating in a state-approved full bilingual program in the third or fourth grade during the 2008-2009 school year. The data were based on the students in the described groups who completed the Spring 2009 administration of the English or Spanish version of the Grade 3 or Grade 4 Mathematics TAKS Test.

Mathematics TAKS Test Scores

Mathematics TAKS Test scores were sampled from the group of students who took the Spring 2009 administration of the English or Spanish version of the Grade 3 or Grade 4 Mathematics TAKS Test in April 2009. Only the scores of students who were enrolled in a two-way dual language immersion program or were not participating in a state-approved full bilingual program during their third- or fourth-grade enrollment were selected for inclusion in the study. The age of students in the third and fourth grades normally ranged from eight to ten years, but the scores of older students were included if they took the specified test and were enrolled in the third or fourth grade at that time. Four different groups of student scores were identified at each grade level: scores of two-way dual language immersion students taking the English version of the test, scores of two-way dual language immersion students taking the Spanish version of the test, scores of students in a monolingual English program taking the English version of the test, and scores of students in a monolingual English program taking the Spanish version of the test. At each grade level, the smallest number of student scores in a group based on test version was noted and an equal-sized sample of student scores was randomly selected for the other group at that grade level from the same version of the test. The main difference in the educational environment for the different groups of student scores was the instructional time in two languages for students in the two-way dual language immersion program; students who were enrolled in a monolingual English program only had instruction as part of a traditional environment with no second language instruction.

Data Used in Analysis

The researcher was responsible for submitting a request to the TEA to access necessary data for the study. The TEA provided the researcher with data that included a coding for sex, ethnicity, economic disadvantage, bilingual indicator, a scaled score, test language version, and an item analysis for every third- and fourth-grade student who took the Spring 2009 version of the Grade 3 or Grade 4 Mathematics TAKS Test. The researcher was only interested in item analysis data for students with a bilingual code of 0 (meaning no participation in bilingual education) and then separately for students with a bilingual code of 4 (meaning participation in a two-way dual language immersion program). The English and the Spanish version of the Spring 2009 Grade 3 Mathematics TAKS Test each consisted of 40 questions, and the Grade 4 Mathematics TAKS Test consisted of 42 questions.

Instrumentation

During the spring of 2009, all third- and fourth-grade students Texas were administered the state-mandated Grade 3 or Grade 4 Mathematics TAKS Test based on their current grade level. "During the 2008-2009 school year, reliability estimates for TAKS assessments were conducted through internal consistency, classical standard error of measurement, conditional standard error of measurement, and classification accuracy" (TEA, 2009c, p. 111). The TEA used the Kuder-Richarson Formula 20 (KR20) to calculate estimates of reliability as shown in Table 2 (TEA, 2009a) and considered estimates of 0.70 to 0.79 as adequate, 0.80 to 0.89 as good, and anything above 0.90 as excellent (TEA, 2009c). The reliability estimate for the total group and all subgroups taking the Grade 3 and Grade 4 Mathematics TAKS Test were considered good or excellent based on the estimates listed above. None of the estimates were rated simply adequate or below.

Table 2
KR20 Reliability Estimates for the Mathematics TAKS Test

	Grade 3 Math English version	Grade 3 Math Spanish version	Grade 4 Math English version	Grade 4 Math Spanish version
Total Group	0.890	0.888	0.902	0.897
Female	0.889	0.885	0.900	0.892
Male	0.892	0.891	0.903	0.902
African American	0.898		0.904	
Asian	0.844		0.874	
Hispanic	0.885		0.899	
Native American	0.881		0.901	
White	0.867		0.884	

Note. Blank cells indicate a lack of reported estimates by specified subgroup. Data compiled from the TEA (Appendix B, 2009a).

"Classical standard error of measurement (SEM) provides a reliability estimate for a test score. The SEM represents the amount of variant in a test score resulting from factors other than achievement" (TEA, 2009c, p. 112). A test that had a perfect reliability would show no difference between the observed score of a student and the true score (TEA, 2009b). Table 3 shows the standard error of measurement reliability estimates for specified subgroups of students provided by the TEA (2009a).

Table 3

Standard Error of Measurement (SEM) Reliability Estimates for the Mathematics TAKS Test

	Grade 3 Math English version	Grade 3 Math Spanish version	Grade 4 Math English version	Grade 4 Math Spanish version
Total Group	2.172	2.292	2.154	2.435
Female	2.167	2.300	2.155	2.446
Male	2.165	2.281	2.161	2.417
African American	2.399		2.407	
Asian	1.650		1.582	
Hispanic	2.264		2.253	
Native American	2.174		2.168	
White	1.984		1.974	

Note. Blank cells indicate a lack of reported estimates by specified subgroup. Data compiled from the TEA (Appendix B, 2009a).

Evidence for validity of the TAKS test was based on test content, the response process, the internal structure of the test, relationships with other variables, and test consequences (TEA, 2009c). To ensure validity of the tests, an established test development process was followed with input from teachers, test development specialists, TEA staff members, test item writers, and reviewers for each stage of development (TEA, 2009c). The content of the test was based on the content outlined in the TEKS by the state of Texas, and test items for the TAKS Tests were carefully aligned with the TEKS (TEA, 2009c). Appendix C contains a copy of the TEKS for Grade 3 and Grade 4. Evidence based on response processes was gathered first through pilot testing of certain types of items and then through reviews by educators and field testing of items (TEA, 2009c). Validity evidence based on internal structure was used to make sure various parts of the test conform to the construct of the test, and studies were also conducted to evaluate the structural comparability between the English and Spanish versions of the TAKS tests (TEA, 2009c). Validity evidence based on relationships to other variables resulted from a comparison of TAKS Test scores with student performance on other external measures (TEA, 2009c). Validity evidence based on consequences of testing resulted from the documentation of both the intended and the unintended consequences of the testing (TEA, 2009c).

Analytic Framework

Organizing the Data

The researcher received comma-delimited text data files from the Texas Education Agency that had to be imported into Excel and organized. Figure 1 shows an image of what these data files actually looked like before the researcher separated the item analysis data and organized questions by type for each test.

A detailed explanation of the organization, breakdown of all initial data, and deletion of data to arrive at appropriate groups for sampling can be found in Appendix A of this document. The researcher deleted student scores based on lack of:

- item analysis data
- a bilingual code of 4 (two-way dual language immersion program) or 0 (not participating in a state-approved full bilingual program)
- a score code of S (meaning the test was scored)
- a mathematics test version of K (which is the regular TAKS Test and not a modified or accommodated version).

Table 4 summarizes the remaining records based on test version and bilingual coding after all other records had been removed from the data sets.

A	B	C	D	E	F	G	H	I	J	K	L	M
MONTH	YEAR	GRADE	SEX	ETHNIC	DISADV	BILING	M_SCODE	M_SSC	M_TESTLANG	M_TESTVER	M_IRS	mask_flag_m
4	9	3	F		1	0	L	2022	S	L		N
4	9	3	F	1			D					N
4	9	3	F	1	0	0	D					N
4	9	3	F	1	0	0	S		E	A		Y
4	9	3	F	1	0	0	S	2222	E	K	++++B++++A+++AC++++ABD++++++++++++++++++	N
4	9	3	F	1	0	0	S	2544	E	K	++++++++++++++++++B+++++++++++++++++++++	N
4	9	3	F	1	0	0	S	2222	E	K	+++++++++A+B++++C++++++CD++++DB+++++++++	N
4	9	3	F	1	0	0	S	2149	E	K	B++DB++C+++++B+++++C+B+++++C++B++B++++++	N
4	9	3	F	1	0	0	S	1984	E	K	+A+++++C+C+CAB++CB++A+DCA+AC+DBAC+++++D+	N
4	9	3	F	1	0	0	S	2544	E	K	++++++++++++++++++++++D+++++++++++++++++	N
4	9	3	F	1	0	0	S	2436	E	K	+++++++++++++A+++++++++++++++++A++++++++	N
4	9	3	F	1	0	0	S	2171	E	K	+++++++D++++++++AB+++C+CA+B++++++BA+++++	N

Figure 1. An Image of the Spring 2009 Grade 3 Mathematics TAKS Test Data Received from the Texas Education Agency.

Table 4
Grade 3 and Grade 4 Mathematics TAKS Data Breakdown of English and Spanish Test Takers with a Bilingual Code of 0 and 4 from Spring 2009

	Number of third-grade test takers	Number of fourth-grade test takers
	279,135	277,348
English test	277,196	275,990
Coded as 0	275,615	274,587
Coded as 4	1,581	1,403
Spanish test	1,939	1,358
Coded as 0	263	205
Coded as 4	1,676	1,153

Note. Bilingual code of 0 = student is not participating in a state-approved full bilingual program, 4 = dual language immersion/two-way

Sampling the Data

Because the English and Spanish versions of each Mathematics TAKS Test were different, the researcher needed equal sample sizes of students coded as 4 and 0 for each grade level and version of the test. For each version of the test, the researcher used the smaller number of students that were coded as 0 or 4. This smaller number was divided into the larger group number for that version of the test to decide which students to sample from the larger group. For example, 1581 third-grade students were coded as 4 and took the English version of the test, so a random sample of 1,581 of the 275,615 students coded as 0 who took the English version of the test was chosen. Because 275,615 divided by 1,581 equals 174.3, the researcher used the modular arithmetic function in Excel to identify every 174th student in the list of 275,615 to yield a sample size of 1,581. This same process was used to select a sample for each version of the test and is described in detail for all versions in Appendix A. Table 5 and Table 6 display the breakdown of the third- and fourth-grade data by various categories at the completion of the sampling to produce equal sample sizes in comparable categories.

Table 5

Sex, Ethnicity, and Economic Disadvantage Classification of Sampled Students Completing the Grade 3 Mathematics TAKS Test in Spring 2009

	Dual language students who took the English test	Students in a monolingual English program who took the English test	Dual language students who took the Spanish test	Students in a monolingual English program who took the Spanish test
Total	1581	1581	263	263
Sex:				
Female	855 (54.1%)	795 (50.3%)	144 (54.8%)	125 (47.5%)
Male	726 (45.9%)	786 (49.7%)	119 (45.2%)	138 (52.5%)
Ethnicity:				
Amer. Indian or Alaskan	0 (0%)	5 (0.3%)	0 (0%)	0 (0%)
Asian or Pacific Islander	4 (0.3%)	78 (4.9%)	0 (0%)	0 (0%)
African American	49 (3.1%)	269 (17.0%)	0 (0%)	7 (2.7%)
Hispanic	1,359 (86.0%)	611 (38.6%)	259 (98.5%)	226 (85.9%)
White, not Hispanic Origin	169 (10.7%)	618 (39.1%)	4 (1.5%)	30 (11.4%)
Economic disadvantage:				
Free meals	768 (48.6%)	612 (38.7%)	153 (58.2%)	133 (50.6%)
Reduced-price meals	144 (9.1%)	150 (9.5%)	21 (8.0%)	24 (9.1%)
Other econ. disadvantage	205 (13.0%)	76 (4.8%)	55 (20.9%)	16 (6.1%)
Not identified economically disadvantaged	464 (29.3%)	743 (47.0%)	34 (12.9%)	90 (34.2%)

Table 6

Sex, Ethnicity, and Economic Disadvantage Classification of Sampled Students Completing the Grade 4 Mathematics TAKS Test in Spring 2009

	Dual language students who took the English test	Students in a monolingual English program who took the English test	Dual language students who took the Spanish test	Students in a monolingual English program who took the Spanish test
Total	1403	1403	205	205
Sex:				
Female	764 (54.5%)	716 (51.0%)	109 (53.2%)	101 (49.3%)
Male	639 (45.5%)	685 (48.8%)	96 (46.8%)	104 (50.7%)
Unknown	0 (0%)	2 (0.1%)	0 (0%)	0 (0%)
Ethnicity:				
Amer. Indian or Alaskan	0 (0%)	5 (0.4%)	0 (0%)	0 (0%)
Asian or Pacific Islander	0 (0%)	59 (4.2%)	0 (0%)	0 (0%)
African American	24 (1.7%)	201 (14.3%)	0 (0%)	0 (0%)
Hispanic	1,245 (88.7%)	564 (40.2%)	202 (98.5%)	186 (90.7%)
White, not Hispanic Origin	134 (9.6%)	573 (40.8%)	3 (1.5%)	19 (9.3%)
Unknown	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)
Economic disadvantage:				
Free meals	729 (52.0%)	523 (37.3%)	107 (52.2%)	113 (55.1%)
Reduced-price meals	131 (9.3%)	148 (10.5%)	27 (13.2%)	14 (6.8%)
Other econ. disadvantage	196 (14.0%)	70 (5.0%)	41 (20.0%)	15 (7.3%)
Not identified economically disadvantaged	347 (24.7%)	661 (47.1%)	30 (14.6%)	63 (30.7%)
Unknown	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)

Organization of Test Questions

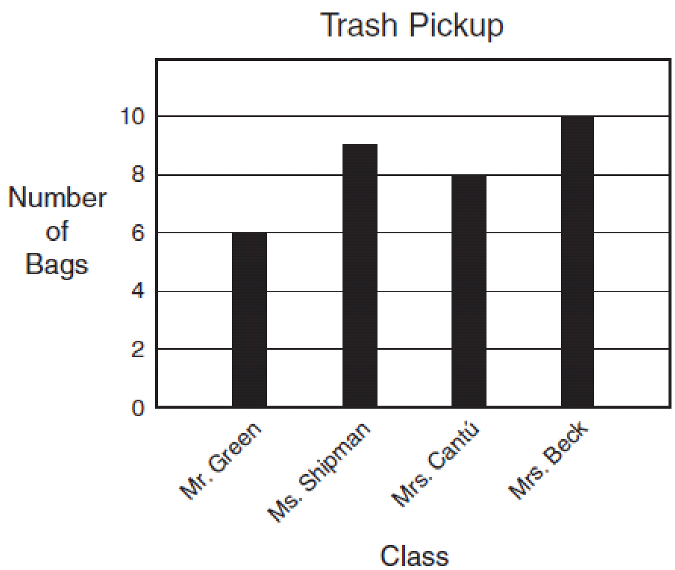
Once data were organized based on grade level, language version, and bilingual coding, individual questions were analyzed on each of the four different tests (Grade 3 English version, Grade 3 Spanish version, Grade 4 English version, and Grade 4 Spanish version). The English and Spanish versions of the Grade 3 and Grade 4 Tests did not contain exactly the same questions, although some similarities were noted at each grade level. The researcher identified questions with visual prompts and questions without visual prompts for each version of the test. A question was considered to have a visual prompt if the question contained any type of visual in the form of a picture, table, graph, or manipulative. Questions with boxes or drawn out spaces as part of a problem were considered visuals as well, unless the box was only representative of the result of a numerical expression as part of the answer choices. Numerical symbols were not considered to be visual prompts.

Once visual questions were identified, the researcher grouped them into categories based on visual type. The categories of visuals that evolved from this analysis included those in the following list, with a brief description of each.

- Graphs – questions with any type of graph such as a pictograph or line graph
- Tables – questions with any type of table with columns to organize information
- Geometric figures – questions with any type of geometric figure such as an image of a two-dimensional figure or three-dimensional solid
- Manipulatives – questions with an image such as pieces of money or a clock that a student could use as a manipulative
- Patterns – questions with a visual based on a pattern

Figures 2 – 6 show samples of each category of visual questions. In Figure 5, the buttons on the shirt can be used as a manipulative if the student counts buttons in groups of 7. Figure 7 shows a sample of a nonvisual question.

1 The fourth-grade classes picked up trash after the school carnival. The graph below shows the number of bags picked up by each class.



Which teacher's class picked up more than 8 but fewer than 10 bags of trash?

A Mr. Green

B Ms. Shipman

C Mrs. Cantú

D Mrs. Beck

Figure 2. A Sample Question with the Visual Image of a Graph from the English Version of the Grade 4 Mathematics TAKS Test (TEA, 2009f, p. 8).

14 Sara quiere comparar las edades de los niños que hay en su familia. La tabla de abajo muestra las edades de los niños.

La familia de Sara

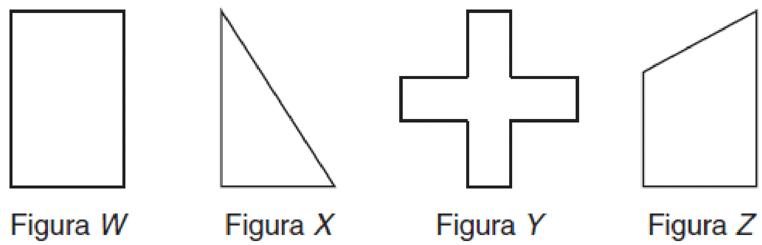
Niño	Edad
Sara	12
Alicia	8
Ronaldo	10

¿Cuál de las siguientes respuestas compara correctamente las edades de los niños? Marca tu respuesta.

- $10 > 8 > 12$
- $8 > 12 < 10$
- $12 > 10 > 8$
- No está aquí.

Figure 3. A Sample Question with the Visual Image of a Table from the Spanish Version of the Grade 3 Mathematics TAKS Test (TEA, 2009e, p. 14).

25 Observa las figuras que aparecen a continuación.



¿Cuál de estas figuras parece tener más de 1 ángulo agudo?

A Figura *W*

B Figura *X*

C Figura *Y*

D Figura *Z*

Figure 4. A Sample Question with the Visual Image of a Geometric Figure from the Spanish Version of the Grade 4 Mathematics TAKS Test (TEA, 2009g, p. 21).

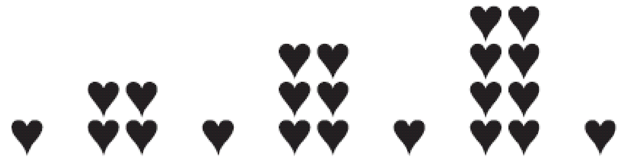
9 Mrs. Rodríguez makes shirts like the one shown below.

Each shirt has the same number of buttons. If Mrs. Rodríguez counts the buttons in groups of 7, which list shows only numbers she will say? Mark your answer.

- 7, 17, 27, 37
- 10, 17, 24, 31
- 14, 22, 26, 32
- 14, 21, 28, 35

Figure 5. A Sample Question with the Visual Image of a Manipulative from the English Version of the Grade 3 Mathematics TAKS Test (TEA, 2009d, p. 11).

18 Natalia drew the following pattern of hearts in her notebook.



If Natalia continues this pattern, which arrangement of hearts will come next? Mark your answer.

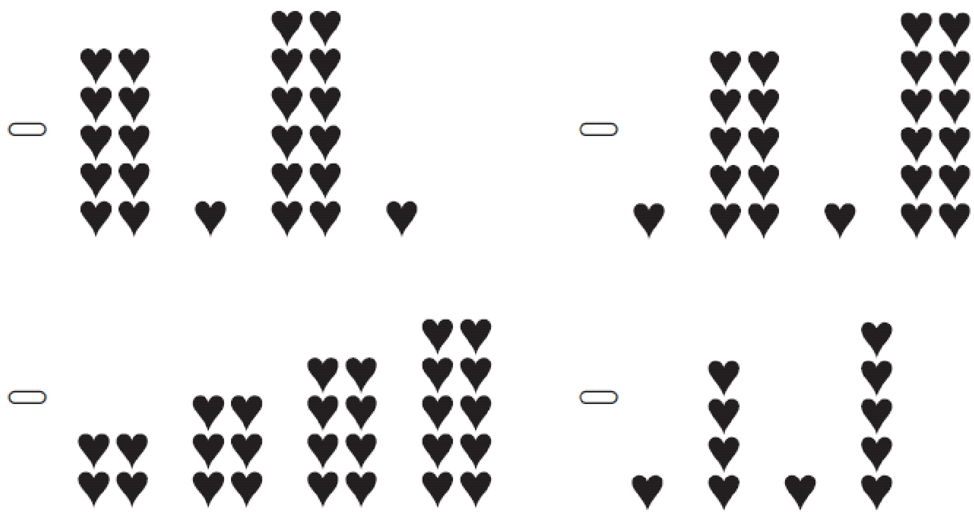


Figure 6. A Sample Question with the Visual Image of a Pattern from the English Version of the Grade 3 Mathematics TAKS Test (TEA, 2009d, p. 17).

9 A teacher handed out textbooks for spelling, reading, math, science, and social studies. There were 22 students in the class. Each student received 1 textbook for each of these subjects. What is the total number of textbooks the teacher handed out?

A 101

B 115

C 110

D 100

Figure 7. A Sample of a Nonvisual Question from the English Version of the Grade 4 Mathematics TAKS Test (TEA, 2009f, p. 12).

To increase the reliability of the identification of visual questions as well as subsets of visual questions, the researcher asked a colleague who teaches mathematics at the college level to perform the same analyses on the TAKS Test questions. The researcher provided the colleague with copies of each of the 4 tests and a grid that contained headings for nonvisual questions, graphs, tables, geometric figures, images that could be used as a manipulative, and patterns. The colleague was asked to place questions in categories and to also make recommendations on categories identified or possibly not identified by the researcher. The colleague first completed this task on the Grade 4 TAKS Tests and compared results with the researcher. At this time, the researcher realized that the colleague was placing each question into only one category and instructions to place them into more than one category as applicable had not been given. This lack of clarity initially affected the agreement on the Grade 4 Spanish Test.

After comparing the Grade 4 TAKS Tests, the colleague continued with the Grade 3 TAKS Tests. At the completion of this task by the colleague, the researcher compared results and discussed discrepancies in the classification of questions until a mutual agreement was reached.

Since the Grade 4 TAKS Tests were categorized by the colleague first with discrepancies resolved, the discussion of the categorization of questions will focus on the Grade 4 TAKS Tests first. On the English version of the Grade 4 Mathematics TAKS Test, the researcher and the colleague originally agreed on the placement of 38 of the 42 questions into categories. Thus, there was original agreement on 90.5% of the questions and the other 9.5% were reviewed and discussed until a mutual agreement was reached on the placement of those questions into categories. Three of the four questions that were originally placed in different categories by the researcher and colleague contained visuals of an answer box as part of the problem, and once analyzed, these problems were categorized as patterns since they mainly focused on the pattern of a fact family. On the Spanish version of the Grade 4 Mathematics TAKS Test, the researcher and the colleague originally agreed on the placement of 33 of the 42 questions into categories. Thus, there was only an agreement on 78.6% of the questions, but the colleague expressed concern that these questions were much more difficult to place into categories because she did not always know how to interpret the questions that did not have an obvious visual such as a table or a graph. Also, the researcher had not instructed the colleague at this time that questions could be placed into more than one category, so two of the discrepancies were a result of that error. Three of the discrepancies once again resulted from problems that contained answer boxes with questions focused on fact families, and the researcher and colleague were then able to agree that these fit into a category of patterns. Thus, the researcher and the colleague reviewed those 21.4% of the questions together and reached a mutual agreement of the placement of those questions into categories.

On each of the English and Spanish versions of the Grade 3 Mathematics TAKS Test, the researcher and colleague originally agreed on the placement of 39 of the 40 questions into categories. Thus, there was original agreement on 97.5% of the questions, and the other 2.5% was adjusted by mutual agreement. Also, for each test, there were 3 questions that the colleague had placed into only one visual category, but a mutual agreement was reached on placing these questions into a second category after discussing the idea that questions can fall into multiple categories if applicable.

Table 7 shows the number of questions in each category based on the English version and the Spanish version of the Grade 3 Mathematics TAKS Test. Table 8 shows the number of questions in each category based on the English version and the Spanish version of the Grade 4 Mathematics TAKS Test. Appendix B shows details of the identification of questions on each test by number and type for study replication purposes.

Table 7

Number of Nonvisual and Visual Questions of Each Type (Graphs, Tables, Geometric, Manipulatives, and Patterns) on the English Version and the Spanish Version of the Spring 2009 Grade 3 Mathematics TAKS Test

Type of Question	Number of Questions	
	English Version	Spanish Version
Questions without a visual	10	13
Questions with a visual:		
Graphs	6	6
Tables	6	5
Geometric Figures	7	6
Images Used as Manipulatives	10	12
Patterns	4	3

Note. Three questions on the English version of the test and five questions on the Spanish version of the test contained visuals that were included as part of two different categories.

Table 8

Number of Nonvisual and Visual Questions of Each Type (Graphs, Tables, Geometric, Manipulatives, and Patterns) on the English Version and the Spanish Version of the Spring 2009 Grade 4 Mathematics TAKS Test

Type of Question	Number of Questions	
	English Version	Spanish Version
Questions without a visual	14	15
Questions with a visual:		
Graphs	5	6
Tables	3	4
Geometric Figures	4	6
Images Used as Manipulatives	10	10
Patterns	6	4

Note. Three questions on the Spanish version of the test contained visuals that were included as part of two different categories.

Analytic Process

Research Question 1 asked, “Are the Grade 3 and Grade 4 Mathematics TAKS Test scaled scores different for students who participated in a two-way dual language immersion environment from those scaled scores of students in a monolingual English program?" To answer this first research question, a one-way between groups ANOVA was conducted to analyze the effect of educational environment on overall scaled scores for the Mathematics TAKS Test. Analyses were conducted for all participants based on grade level and test language version. Thus, the separate analyses of the Mathematics TAKS Test scaled scores included both two-way dual language immersion students and students in a monolingual English program who each took one of the following: Grade 3 English version of the test, Grade 3 Spanish version of the test, Grade 4 English version of the test, and Grade 4 Spanish version of the test.

Research Question 2 asked, "Are percentages of correct responses on nonvisual questions and various categories of visual questions on the Grade 3 and Grade 4 Mathematics TAKS Test different for students who participated in a two-way dual language immersion environment from those percentages of correct responses of students in a monolingual English program?" To answer this second research question, the researcher first identified visual and nonvisual questions on each version of the test. Subgroups of particular types of visual questions were also identified. Multiple one-way between groups ANOVAs were conducted to analyze the effect of educational environment on percentages of correct responses on nonvisual questions and various categories of visual questions. Analyses were conducted for all participants based on grade level and test language version. Thus, the separate analyses of the Mathematics TAKS Test percentages of correct responses included both two-way dual language immersion students and students in a monolingual English program who each took one of the following: Grade 3 English Mathematics TAKS Test, Grade 3 Spanish Mathematics TAKS Test, Grade 4 English Mathematics TAKS Test, and Grade 4 Spanish Mathematics TAKS Test. For each of these groups, comparisons between two-way dual language immersion students and students in a monolingual English program were made using: percentages correct of nonvisual questions, visual questions, graph questions, table questions, geometry questions, manipulative questions, and pattern questions.

Research Question 3 asked, "For students who participated in a two-way dual language immersion environment, are the percentages of correct responses on the Grade 3 and Grade 4 Mathematics TAKS Test for questions with certain types of visual prompts different from the percentages of correct responses for questions without a visual prompt?" To answer this third research question, the researcher used the same identified nonvisual questions and various categories of visual questions from question two. Multiple one-way ANOVAs were conducted to analyze the effect of question type on Mathematics TAKS Test performance of students in a two-way dual language immersion program. Analyses were conducted for all participants in this setting based on grade level and test language version. Thus, the separate analyses of the Mathematics TAKS Test subgroups of nonvisual and visual questions included two-way dual language immersion students who each took one of the following: English version of the Grade 3 Mathematics TAKS Test, Spanish version of the Grade 3 Mathematics TAKS Test, English version of the Grade 4 Mathematics TAKS Test, and Spanish version of the Grade 4 Mathematics TAKS Test. For each of these groups, comparisons were made of the percentages correct of nonvisual questions versus each of the following: visual questions, graph questions, table questions, geometry questions, manipulative questions, and pattern questions.

Research Question 4 asked, "For students in a monolingual English program, are the percentages of correct responses on the Grade 3 and Grade 4 Mathematics TAKS Test for questions with certain types of visual prompts different from the percentages of correct responses for questions without a visual prompt?" For this fourth research question, the same identified questions and analyses from question three were conducted for the participants who did not participate in a bilingual program.

Research Question 5 asked, "Are there any main effects or an interaction effect between question type (visual category versus nonvisual) and instructional environment (two-way immersion versus monolingual education program) on the Grade 3 and Grade 4 Mathematics TAKS Test scores?" This fifth research question was analyzed using a 2x2 Mixed Between-Within ANOVA with factors of question type (visual and nonvisual) and educational program (two-way dual language and monolingual education). Different analyses were conducted utilizing all identified nonvisual questions and then various subgroups of visual questions. The independent variables included educational program and question type. The educational program was an independent measure (between-subjects factor) while the question type was a repeated measure (within-subjects factor). A 2x2 Mixed Between-Within ANOVA was chosen to analyze the data because of the mix of between- and within-subjects factors.

Table 9 summarizes the focus for each of the research questions and lists the groups included in the analyses for that question. The separate analyses based on test version are also listed for each research question along with the selected statistical technique.

Table 9

Identification of the Focus, Groups, Analyses, and Statistical Technique for Each Research Question

Research Question	Focus	Group(s)	Separate Analyses (test version)	Statistical Technique
1	Scaled Scores	Two-way and Monolingual	3rd Grade English 3rd Grade Spanish 4th Grade English 4th Grade Spanish	One-way Between Groups ANOVA
2	Nonvisual, All Visual, Graphs, Tables, Geometric, Manipulatives, Patterns	Two-way and Monolingual	3rd Grade English 3rd Grade Spanish 4th Grade English 4th Grade Spanish	Multiple One-way Between Groups ANOVAs
3	Nonvisual, All Visual, Graphs, Tables, Geometric, Manipulatives, Patterns	Two-way	3rd Grade English 3rd Grade Spanish 4th Grade English 4th Grade Spanish	Multiple One-way ANOVAs
4	Nonvisual, All Visual, Graphs, Tables, Geometric, Manipulatives, Patterns	Monolingual	3rd Grade English 3rd Grade Spanish 4th Grade English 4th Grade Spanish	Multiple One-way ANOVAs
5	Factors of Question Type (Visual and Nonvisual) and Educational Program (Two-way and Monolingual Education)	Two-way and Monolingual	3rd Grade English 3rd Grade Spanish 4th Grade English 4th Grade Spanish	2x2 Mixed Between-Within ANOVAs

Note. Two-way refers to the students enrolled in two-way dual language immersion programs. Monolingual refers to the students who did not participate in a bilingual educational program.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Organization of the Presentation of Findings

The presentation and analysis of data are arranged into five different sections. The first section focuses on the first research question, centered on comparing the scaled scores of students who participated in a two-way dual language immersion program to those in a monolingual English program. The next section focuses on the second research question, centered on comparing percentages of correct responses on nonvisual questions and various categories of visual questions of students who participated in a two-way dual language immersion program to those in a monolingual English program. The third section focuses on the third research question, centered on comparing the performance of dual language immersion students on nonvisual questions from the Mathematics TAKS Test to visual questions and various subsets of visual questions. The fourth section focuses on the fourth research question, centered on comparing the performance of students in a monolingual English program on nonvisual questions from the Mathematics TAKS Test to visual questions and various subsets of visual questions. The final section focuses on the fifth research question to analyze the interaction effect of question type (visual and nonvisual) with program type (dual language and monolingual English education) and the main effects of question type and program type.

Research Question 1: Analyses of Scaled Score Differences

To answer the first research question, an ANOVA was conducted to analyze the differences in overall scaled scores for the Mathematics TAKS Test based on educational environment. Four different analyses of scaled scores were conducted: Grade 3 English Test, Grade 3 Spanish Test, Grade 4 English Test, and Grade 4 Spanish Test. Table 10 lists the descriptive statistics for each of these four groups based on an educational setting of a two-way dual language immersion program or an educational setting where students participate in a monolingual English program. In each group except for the Grade 3 Spanish, the two-way immersion students had a higher scaled score mean and lower standard deviation. Figure 8 provides a visual comparison of the scaled scores for all students, students enrolled in two-way dual language immersion programs, and students in a monolingual English program who took the English or the Spanish version of the Grade 3 or Grade 4 Mathematics TAKS Test. In each case, the two-way dual language immersion students scored at or above the level of all students and the level of students in a monolingual English program.

Table 10

Descriptive Statistics for the Spring 2009 Mathematics TAKS Test Scaled Scores

	N	Mean	Standard Deviation	95% Confidence Interval for Mean
Grade 3 English Test:	3162	2304.36	199.798	2297.40 – 2311.33
Two-way immersion	1581	2311.14	195.038	2301.52 – 2320.76
Monolingual	1581	2297.59	204.285	2287.51 – 2307.66
Grade 3 Spanish Test:	526	2262.56	212.002	2244.40 – 2280.72
Two-way immersion	263	2261.59	193.710	2238.07 – 2285.11
Monolingual	263	2263.54	229.206	2235.71 – 2291.37
Grade 4 English Test:	2806	2330.88	205.153	2323.27 – 2338.45
Two-way immersion	1403	2332.17	203.727	2321.50 – 2342.84
Monolingual	1403	2329.55	206.634	2318.73 – 2340.37
Grade 4 Spanish Test:	410	2331.41	264.456	2305.73 – 2357.08
Two-way Immersion	205	2357.59	236.873	2324.97 – 2390.20
Monolingual	205	2305.23	287.630	2265.62 – 2344.84

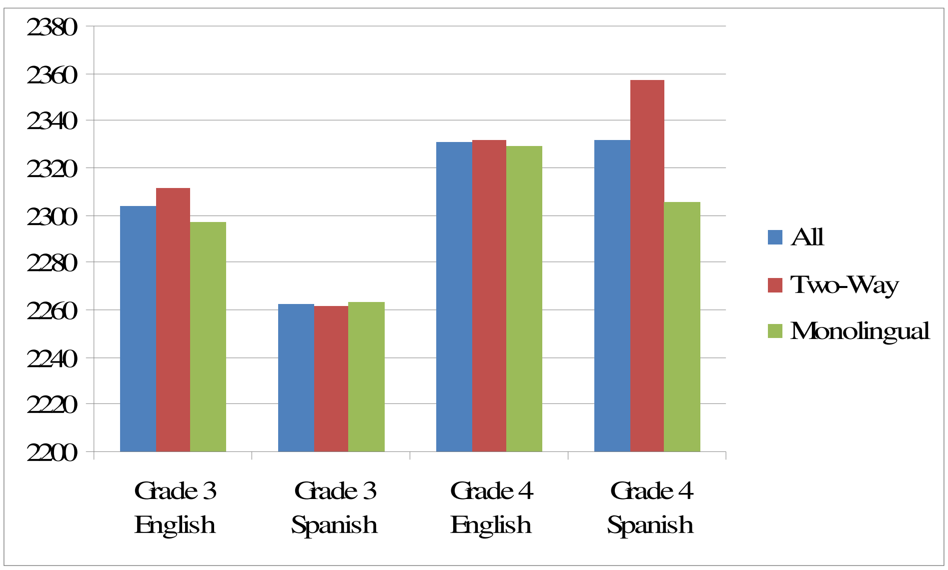


Figure 8. Comparisons of Scaled Scores for All Students, Two-Way Dual Language Immersion Students, and Students in a Monolingual English Program on the English Version and Spanish Version of the Grade 3 and Grade 4 Mathematics TAKS Test.

Table 11 lists significance values for each one-way ANOVA used to analyze the Mathematics TAKS scaled scores based on the educational setting of a two-way dual language immersion program or an educational setting where students participated in a monolingual English program. Five different assumptions had to be met including the measurement of the dependent variable on an interval or ratio scale, the use of random sampling, independence of data observations from one another, normal distribution of data from the populations sampled, and similar variabilities of scores from each group (Pallant, 2007). Given that the first three assumptions were met and that the sample size was large enough that a violation of the normal distribution of data would not cause major problems according to Pallant (2007), the researcher used a Lavene statistic to test for the homogeneity of variances. According to Pallant (2007), the Welch robust test of equality of means should be consulted anytime a violation of homogeneity of variances occurs. Thus, the Welch significant value was reported in these cases in Table 11 while the regular significance value was reported in all other cases. The only statistically significant difference that occurred between the scaled scores of two-way dual language immersion students and students who participated in a monolingual English program was on the Spanish version of the Grade 4 Mathematics TAKS Test.

Table 11
Summaries of One-Way ANOVAs to Analyze Spring 2009 Mathematics TAKS Test Scaled Scores Based on the Factor of Educational Setting (Two-Way Immersion and Monolingual English)

Source	*df*	*SS*	*MS*	F	p
Grade 3 English Test:					
Between groups	1	145170.976	145170.976	3.640	.057
Within groups	3160	126040104.400	39886.109		
Total	3161	126185275.376			
Grade 3 Spanish Test:					
Between groups	1	502.274	502.274	.011	.916
Within groups	524	23595483.150	45029.548		
Total	525	23595985.424			
Grade 4 English Test:					
Between groups	1	4826.230	4826.230	.115	.735
Within groups	2804	118051815.300	42101.218		
Total	2805	118104826.230			
Grade 4 Spanish Test:					
Between groups	1	280968.998	280968.998	4.047**	.045
Within groups	408	28323293.900	69419.838		
Total	409	28600968.998			

**p < .05

In the comparison of dual language immersion students (M = 2311.14, SD = 195.038) to students in a monolingual English program (M = 2297.59, SD = 204.285) on the English version of the Grade 3 Mathematics TAKS Test, no statistically significant difference was found, F(1,3160) = 3.640, p = .057. In the comparison of dual language immersion students (M = 2261.59, SD = 193.710) to students in a monolingual English program (M = 2263.54, SD = 229.206) on the Spanish version of the Grade 3 Mathematics TAKS Test, no statistically significant difference was found, F(1,524) = .011, p = .916.

In the comparison of dual language immersion students (M = 2332.17, SD = 203.727) to students in a monolingual English program (M = 2329.55, SD = 206.634) on the English version of the Grade 4 Mathematics TAKS Test, no statistically significant difference was found, $F(1,2804) = .115$, $p = .735$. In the comparison of dual language immersion students (M = 2357.59, SD = 236.873) to students in a monolingual English program (M = 2305.23, SD = 287.630) on the Spanish version of the Grade 4 Mathematics TAKS Test, a statistically significant difference was found, $F(1,408) = 4.047$, $p = .045$. Dual language immersion students had the higher mean when compared to the mean of students in a monolingual English program.

Research Question 2: Analyses of Percentages of Correct Responses on Nonvisual Questions and Various Categories of Visual Questions

To answer the second research question, the researcher first identified visual and nonvisual questions on each version of the test. Subgroups of particular types of visual questions were also identified. Multiple ANOVAs were conducted to analyze the differences in percentages of correct responses on nonvisual and visual questions for the Mathematics TAKS Test based on educational environment. Seven different analyses were conducted for four different groups. The different analyses included percentages correct of: nonvisual questions, visual questions, graph questions, table questions, geometry questions, manipulative questions, and pattern questions. The four different groups of students included those who took the: Grade 3 English Mathematics TAKS Test, Grade 3 Spanish Mathematics TAKS Test, Grade 4 English Mathematics TAKS Test, and Grade 4 Spanish Mathematics TAKS Test. Table 12 lists the descriptive statistics for each of these four groups based on an educational setting of a two-way dual language immersion program or an educational setting where students participate in a monolingual English program. In each analysis except for the graphs, tables, and patterns on the Grade 3 Spanish Mathematics TAKS Test and the nonvisual and graphs on the Grade 4 English Mathematics TAKS Test, two-way immersion students have a higher mean percentage of correct responses.

Figure 9 provides a graph of the means of percentages of correct responses for the comparison of two-way dual language immersion students to students in a monolingual English program on nonvisual questions and the various categories of visual questions on the Grade 3 English Mathematics TAKS Test. The two-way dual language immersion students are higher in every category, with a statistically significant difference in all comparisons except for the category of tables. Figure 10 provides a graph of the means of percentages of correct responses for the comparison of two-way dual language immersion students to students in a monolingual English program on nonvisual questions and the various categories of visual questions on the Grade 3 Spanish Mathematics TAKS Test. The two-way dual language immersion students are higher in every category except graphs, tables, and patterns. No comparisons show a statistically significant difference, except for the category of geometric problems. Figure 11 provides a graph of the means of percentages of correct responses for the comparison of two-way dual language immersion students to students in a monolingual English program on nonvisual questions and the various categories of visual questions on the Grade 4 English Mathematics TAKS Test. The performances of both groups are almost the same except for tables.

Table 12

Descriptive Statistics for the Spring 2009 Mathematics TAKS Test Percentages of Correct Responses on Nonvisual Questions and Various Categories of Visual Questions

	Two-way immersion mean	Monolingual Education mean
Grade 3 English Test: (N = 1581)		
Nonvisual	81.031	79.481
Visual	85.454	84.187
Graphs	90.723	88.541
Tables	83.291	82.269
Geometric Figures	89.717	88.443
Manipulatives	86.483	85.218
Patterns	74.557	73.071
Grade 3 Spanish Test: (N = 263)		
Nonvisual	74.408	74.115
Visual	82.890	81.214
Graphs	84.221	84.728
Tables	79.316	81.065
Geometric Figures	91.445	87.516
Manipulatives	82.795	80.038
Patterns	71.736	73.257
Grade 4 English Test: (N = 1403)		
Nonvisual	84.391	84.528
Visual	85.307	84.783
Graphs	86.999	87.512
Tables	83.583	81.492
Geometric Figures	87.812	87.491
Manipulatives	85.652	84.740
Patterns	82.514	82.419
Grade 4 Spanish Test: (N = 205)		
Nonvisual	82.265	77.213
Visual	82.108	77.334
Graphs	90.829	85.268
Tables	78.211	69.268
Geometric Figures	77.927	72.805
Manipulatives	81.220	76.634
Patterns	81.057	78.943

No comparisons show a statistically significant difference except for the category of tables, and two-way dual language immersion students have the higher mean. Figure 12 provides a graph of the means of percentages of correct responses for the comparison of two-way dual language immersion students to students in a monolingual English program on nonvisual questions and the various categories of visual questions on the Grade 4 Spanish Mathematics TAKS Test. The two-way dual language immersion students are higher in every category, with a statistically significant difference in all comparisons except for the category of patterns.

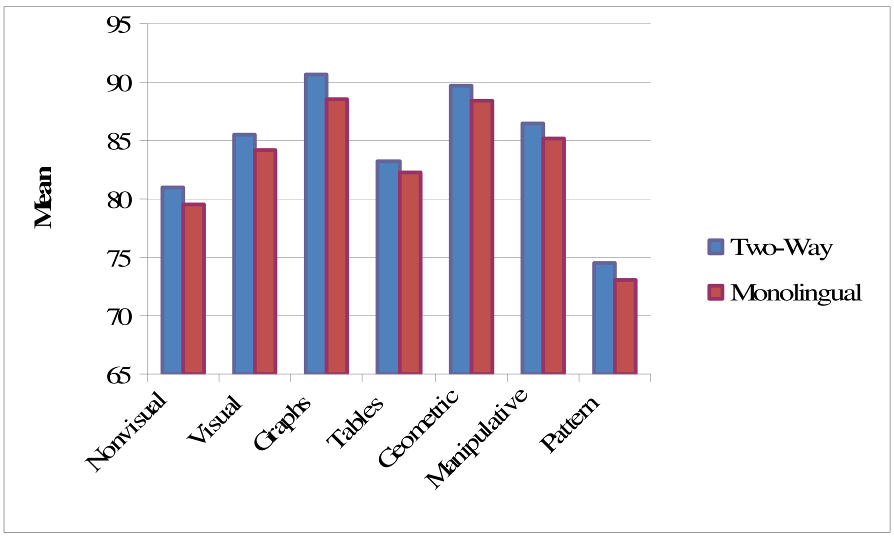


Figure 9. Comparison of Two-Way Dual Language Immersion Students to Students in a Monolingual English Program on the Means of the Percentages of Correct Responses from Nonvisual Questions and Various Categories of Visual Questions on the Grade 3 English Mathematics TAKS Test.

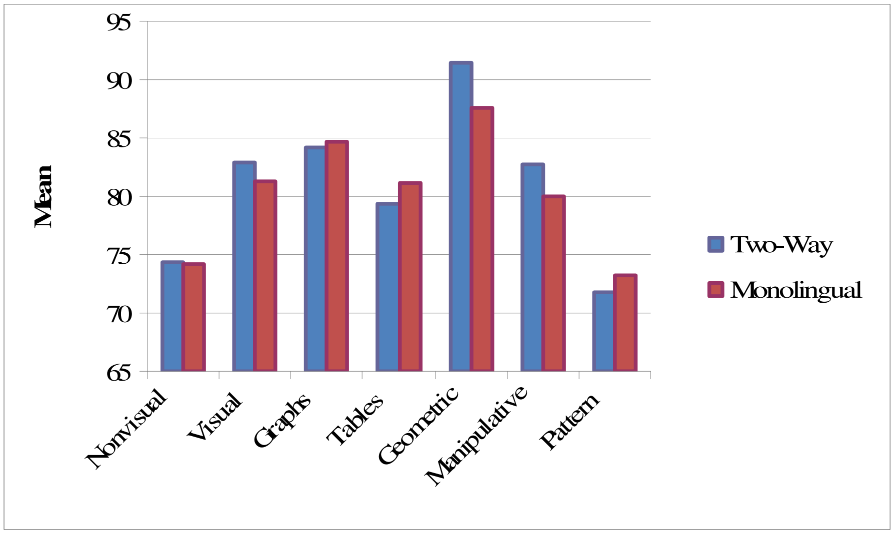


Figure 10. Comparison of Two-Way Dual Language Immersion Students to Students in a Monolingual English Program on the Means of the Percentages of Correct Responses from Nonvisual Questions and Various Categories of Visual Questions on the Grade 3 Spanish Mathematics TAKS Test.

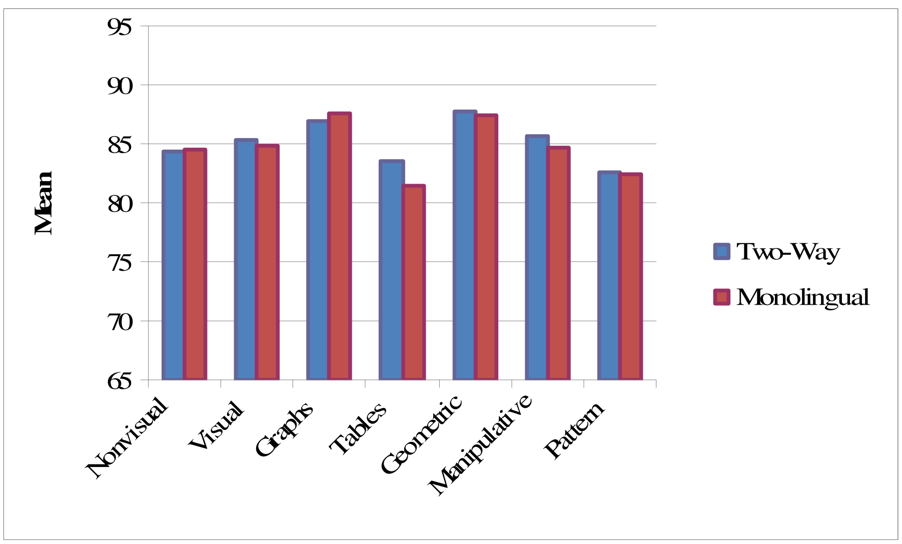


Figure 11. Comparison of Two-Way Dual Language Immersion Students to Students in a Monolingual English Program on the Means of the Percentages of Correct Responses from Nonvisual Questions and Various Categories of Visual Questions on the Grade 4 English Mathematics TAKS Test.

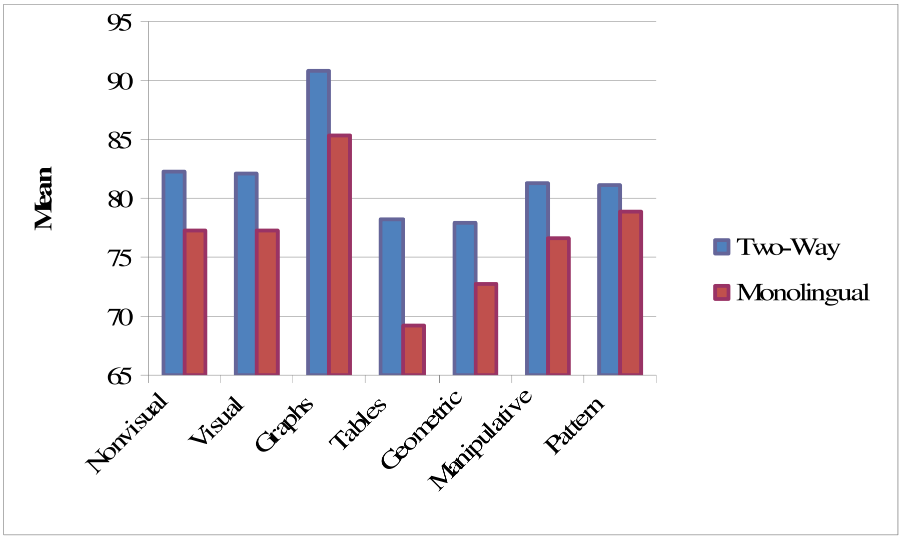


Figure 12. Comparison of Two-Way Dual Language Immersion Students to Students in a Monolingual English Program on the Means of the Percentages of Correct Responses from Nonvisual Questions and Various Categories of Visual Questions on the Grade 4 Spanish Mathematics TAKS Test.

Tables 13 – 16 summarize the one-way ANOVAs used to analyze the Mathematics TAKS Test percentages of correct responses in various categories based on the educational setting of a two-way dual language immersion program or an educational setting where students participate in a monolingual English program. Five different assumptions had to be met including the measurement of the dependent variable on an interval or ratio scale, the use of random sampling, independence of data observations from one another, normal distribution of data from the populations sampled, and similar variabilities of scores from each group (Pallant, 2007). Given that the first three assumptions were met and that the sample size was large enough that a violation of the normal distribution of data would not cause major problems according to Pallant (2007), the researcher used a Lavene statistic to test for the homogeneity of variances.

Table 13

Summaries of One-Way ANOVAs to Analyze Spring 2009 Grade 3 English Mathematics TAKS Test Subset Scores Based on the Factor of Educational Setting (Two-Way Immersion and Monolingual)

Source	*df*	*SS*	*MS*	F	p
Nonvisual:					
Between groups	1	1898.324	1898.324	5.209**	.023
Within groups	3160	1151594.181	364.429		
Total	3161	1153492.505			
Visual:					
Between groups	1	1269.242	1269.242	6.034**	.014
Within groups	3160	664745.871	210.363		
Total	3161	666015.114			
Graphs:					
Between groups	1	3764.231	3764.231	12.738**	.000
Within groups	3160	9333841.099	295.519		
Total	3161	937605.331			
Tables:					
Between groups	1	826.569	826.569	1.990	.158
Within groups	3160	1312371.565	415.307		
Total	3161	1313198.134			
Geometric Figures:					
Between groups	1	1283.158	1283.158	5.224**	.022
Within groups	3160	776159.754	245.620		
Total	3161	777442.913			
Manipulatives:					
Between groups	1	1265.022	1265.022	4.447**	.035
Within groups	3160	898896.521	284.461		
Total	3161	900161.543			
Patterns:					
Between groups	1	1746.521	1746.521	2.689	.101
Within groups	3160	2052556.135	649.543		
Total	3161	2054302.657			

**$p < .05$

Table 14

Summaries of One-Way ANOVAs to Analyze Spring 2009 Grade 3 Spanish Mathematics TAKS Test Subset Scores Based on the Factor of Educational Setting (Two-Way Immersion and Monolingual)

Source	*df*	*SS*	*MS*	F	p
Nonvisual:					
Between groups	1	11.249	11.249	.024	.876
Within groups	524	242298.018	462.401		
Total	525	242309.267			
Visual:					
Between groups	1	369.301	369.301	1.364	.243
Within groups	524	141887.580	270.778		
Total	525	142256.881			
Graphs:					
Between groups	1	33.798	33.798	.084	.772
Within groups	524	211504.014	403.634		
Total	525	211537.812			
Tables:					
Between groups	1	402.281	402.281	.867	.352
Within groups	524	243178.707	464.082		
Total	525	243580.989			
Geometric Figures:					
Between groups	1	2029.996	2029.996	7.672**	.006
Within groups	524	138650.190	264.600		
Total	525	140680.186			
Manipulatives:					
Between groups	1	999.287	999.287	2.782	.096
Within groups	524	188248.310	359.253		
Total	525	189247.597			
Patterns:					
Between groups	1	304.183	304.183	.376	.540
Within groups	524	424038.868	809.234		
Total	525	424343.050			

**$p < .05$

Table 15

Summaries of One-Way ANOVAs to Analyze Spring 2009 Grade 4 English Mathematics TAKS Test Subset Scores Based on the Factor of Educational Setting (Two-Way Immersion and Monolingual)

Source	*df*	*SS*	*MS*	F	p
Nonvisual:					
Between groups	1	13.255	13.255	.042	.838
Within groups	2804	888169.520	316.751		
Total	2805	888182.775			
Visual:					
Between groups	1	192.899	192.899	.858	.354
Within groups	2804	630462.693	224.844		
Total	2805	630655.592			
Graphs:					
Between groups	1	184.747	184.747	.594	.441
Within groups	2804	872085.531	311.015		
Total	2805	872270.278			
Tables:					
Between groups	1	3066.445	3066.445	4.394**	.036
Within groups	2804	1956822.682	697.868		
Total	2805	1959889.126			
Geometric Figures:					
Between groups	1	72.167	72.167	.210	.647
Within groups	2804	964550.962	343.991		
Total	2805	964623.129			
Manipulatives:					
Between groups	1	583.892	583.892	1.853	.174
Within groups	2804	883658.304	315.142		
Total	2805	884242.195			
Patterns:					
Between groups	1	6.336	6.336	.015	.903
Within groups	2804	1198994.615	427.602		
Total	2805	1199000.950			

**$p < .05$

Table 16

Summaries of One-Way ANOVAs to Analyze Spring 2009 Grade 4 Spanish Mathematics TAKS Test Subset Scores Based on the Factor of Educational Setting (Two-Way Immersion and Monolingual)

Source	*df*	*SS*	*MS*	F	p
Nonvisual:					
Between groups	1	2616.351	2616.351	9.031**	.003
Within groups	408	118202.588	289.712		
Total	409	120818.940			
Visual:					
Between groups	1	2335.615	2335.615	8.064**	.005
Within groups	408	118168.243	289.628		
Total	409	120503.858			
Graphs:					
Between groups	1	3169.756	3169.756	9.273**	.002
Within groups	408	139469.268	341.836		
Total	409	142639.024			
Tables:					
Between groups	1	8197.832	8197.832	7.114**	.008
Within groups	408	470178.862	1152.399		
Total	409	478376.694			
Geometric Figures:					
Between groups	1	2689.024	2689.024	4.624**	.032
Within groups	408	237256.098	581.510		
Total	409	239945.122			
Manipulatives:					
Between groups	1	2155.122	2155.122	5.078**	.025
Within groups	408	173172.683	424.443		
Total	409	175327.805			
Patterns:					
Between groups	1	457.995	457.995	1.214	.271
Within groups	408	153875.339	377.145		
Total	409	154333.333			

**$p < .05$

According to Pallant (2007), the Welch robust test of equality of means should be consulted anytime a violation of homogeneity of variances occurs. For this study, the Welch test had to be used for 17 of the 28 comparisons. A statistically significant difference at the .05 level was found in 13 of the 28 comparisons. Most of those statistically significant differences occurred on the Grade 4 Spanish Mathematics TAKS Test (6 of the 7 comparisons for this test version). Table 17 summarizes where the significant differences occurred and identifies the group with the higher mean. The results of the Grade 3 English Test were similar to the results of the Grade 4 Spanish Test with the exception in the area of tables. The results of the Grade 3 Spanish Test were similar to the results of the Grade 4 English Test with the exceptions in the areas of geometric visuals and tables. In all cases where a statistically significant difference was found, the students in the two-way dual language immersion program had a higher mean than those in the monolingual English program.

Table 17
Statistical Results from Research Question 2 Focused on Differences in Performance on Visual and Nonvisual Questions for Students Who Participated in a Two-Way Dual Language Immersion Environment and Students in a Monolingual English Program

	Statistically Significant Difference	Group of Students With a Higher Mean	Not a Statistically Significant Difference
Grade 3 English Test	Nonvisual Visual Graphs Geometric Manipulatives	Two-way Two-way Two-way Two-way Two-way	Tables Patterns
Grade 3 Spanish Test	Geometric	Two-way	Nonvisual Visual Graphs Tables Manipulatives Patterns
Grade 4 English Test	Tables	Two-way	Nonvisual Visual Graphs Geometric Manipulatives Patterns
Grade 4 Spanish Test	Nonvisual Visual Graphs Tables Geometric Manipulatives	Two-way Two-way Two-way Two-way Two-way Two-way	Patterns

Note. Two-way refers to those students enrolled in a two-way dual language immersion program. Monolingual refers to those students enrolled in a monolingual English program.

Research Question 3: Analyses of Visual and Nonvisual Questions for Students Who Participated in a Two-Way Dual Language Immersion Environment

To answer the third research question, the same identified visual and nonvisual questions and subgroups of particular types of visual questions were used as for research question two. Multiple one-way ANOVAs were conducted to analyze the effect of question type on Mathematics TAKS Test performance of students in a two-way dual language environment. Analyses were conducted for all participants in this setting based on grade level and test language version. Four different comparisons were made for students taking the Mathematics TAKS Test in two-way dual language immersion programs including the English version of the Grade 3 Mathematics TAKS Test, Spanish version of the Grade 3 Mathematics TAKS Test, English version of the Grade 4 Mathematics TAKS Test, and Spanish version of the Grade 4 Mathematics TAKS Test. The subsets of questions included nonvisual questions, all questions with a visual, questions containing a visual of a graph, questions containing a visual of a table, questions containing a visual of a geometric figure, questions containing a visual that can be used as a manipulative, and questions containing a visual related to a pattern. Five different assumptions had to be met including the measurement of the dependent variable on an interval or ratio scale, the use of random sampling, independence of data observations from one another, normal distribution of data from the populations sampled, and similar variabilities of scores from each group (Pallant, 2007). Given that the first three assumptions were met and that the sample size was large enough that a violation of the normal distribution of data would not cause major problems, the researcher interpreted the multivariate statistics provided by SPSS since the sphericity assumption focused on similar variabilities is not required (Pallant, 2007). According to Pallant (2007), the Wilks' Lambda is the most commonly reported statistic used in this type of analysis.

Table 18 lists the breakdown of data by question type, mean, and standard deviation, with question type arranged from highest mean to lowest mean for each version of the test for students enrolled in a two-way dual language immersion program. For the Grade 3 English Mathematics TAKS Test, the subset of visual questions including graphs had the highest mean for correct responses (M = 90.723), and the subset of visual questions including patterns had the lowest mean for correct responses (M = 74.557). For the Spanish version of the Grade 3 Mathematics TAKS Test, the subset of visual questions including geometric figures had the highest mean of correct responses (M = 91.445), and the subset of visual questions including patterns had the lowest mean of correct responses (M = 71.736). For the English version of the Grade 4 Mathematics TAKS Test, the subset of visual questions including geometric figures had the highest mean of correct responses (M = 87.812), and the subset of visual questions including patterns had the lowest mean of correct responses (M = 82.514). For the Grade 4 Spanish version of the test, the subset of visual questions including graphs had the highest mean of correct responses (M = 90.829), and the subset of visual questions including geometric figures had the lowest mean of correct responses (M = 77.927).

Table 18

Mean Score and Standard Deviation Values for One-Way ANOVAs to Analyze Subset Scores on the Spring 2009 Mathematics TAKS Test for Students in a Two-Way Dual Language Immersion Program

	Question Type	Mean Score	Standard Deviation
Grade 3:			
English Test	Graphs	90.723	16.413
(N = 1581)	Geometric	89.717	15.141
	Manipulatives	86.291	16.363
	All Visual	85.454	13.952
	Tables	83.291	19.986
	Nonvisual	81.031	18.569
	Patterns	74.557	24.742
	Geometric	91.445	13.803
Spanish Test	Graphs	84.221	19.571
(N = 263)	All Visual	82.890	14.683
	Manipulatives	82.795	16.442
	Tables	79.316	21.639
	Nonvisual	74.408	19.789
	Patterns	71.736	29.551
Grade 4:			
English Test	Geometric	87.812	18.267
(N = 1403)	Graphs	86.999	18.280
	Manipulatives	85.652	17.310
	All Visual	85.307	14.733
	Nonvisual	84.391	17.744
	Tables	83.583	25.658
	Patterns	82.514	20.406
	Graphs	90.829	14.342
Spanish Test	Nonvisual	82.265	14.470
(N = 205)	All Visual	82.108	14.768
	Manipulatives	81.220	18.968
	Patterns	81.057	17.315
	Tables	78.211	31.692
	Geometric	77.927	22.632

Table 19 summarizes each one-way ANOVA used to analyze subset scores on the Spring 2009 Mathematics TAKS Test for students in a two-way dual language immersion program. A statistically significant difference at the .05 level between nonvisual questions and all visual questions was found on the Grade 3 English test ($p = .000$), Grade 3 Spanish test ($p = .000$), and Grade 4 English test ($p = .002$). When comparing various subsets of visual questions to nonvisual questions, a statistically significant difference with $p = .000$ was found for all comparisons (nonvisual/graphs, nonvisual/tables, nonvisual/geometric figures, nonvisual/manipulatives, nonvisual/patterns) on the English version of the Grade 3 Mathematics TAKS Test. When comparing various subsets of visual questions to nonvisual questions on the Spanish version of the Grade 3 Mathematics TAKS Test, a statistically significant difference was found for all comparisons ($p = .000$) except for nonvisual questions compared to questions with a pattern visual ($p = .113$). When comparing various subsets of visual questions to nonvisual questions on the English version of the Grade 4 Mathematics TAKS Test, a statistically significant difference at the .05 level was found for all comparisons ($p \leq .002$) except for nonvisual questions compared to questions containing a visual of a table ($p = .166$). When comparing various subsets of visual questions to nonvisual questions on the Spanish version of the Grade 4 Mathematics TAKS Test, a statistically significant difference at the .05 level was found in only two comparisons: nonvisual questions compared to questions with a graph ($p = .000$) and nonvisual questions compared to questions with a visual of a geometric figure ($p = .002$).

Each of the other comparisons for this version of the test had no statistically significant differences at the .05 level.

Table 19
Summaries for One-Way ANOVAs to Analyze Subset Scores on the Spring 2009 Mathematics TAKS Test for Students in a Two-Way Dual Language Immersion Program

	F	Hypothesis df	Error df	p	Partial Eta Squared
Grade 3 English Test:					
Nonvisual/All Visual	185.7	1	1580	.000	.105
Nonvisual/Graphs	538.4	1	1580	.000	.254
Nonvisual/Tables	24.9	1	1580	.000	.015
Nonvisual/Geometric	398.5	1	1580	.000	.201
Nonvisual/Manipulatives	215.5	1	1580	.000	.120
Nonvisual/Patterns	129.2	1	1580	.000	.076
Grade 3 Spanish Test:					
Nonvisual/All Visual	116.3	1	262	.000	.307
Nonvisual/Graphs	79.9	1	262	.000	.234
Nonvisual/Tables	18.9	1	262	.000	.067
Nonvisual/Geometric	216.1	1	262	.000	.452
Nonvisual/Manipulatives	90.4	1	262	.000	.257
Nonvisual/Patterns	2.5	1	262	.113	.010
Grade 4 English Test:					
Nonvisual/All Visual	9.3	1	1402	.002	.007
Nonvisual/Graphs	41.2	1	1402	.000	.029
Nonvisual/Tables	1.9	1	1402	.166	.001
Nonvisual/Geometric	41.6	1	1402	.000	.029
Nonvisual/Manipulatives	10.9	1	1402	.001	.008
Nonvisual/Patterns	17.3	1	1402	.000	.012
Grade 4 Spanish Test:					
Nonvisual/All Visual	.04	1	204	.839	.000
Nonvisual/Graphs	77.9	1	204	.000	.276
Nonvisual/Tables	3.9	1	204	.050	.019
Nonvisual/Geometric	9.8	1	204	.002	.046
Nonvisual/Manipulatives	1.1	1	204	.298	.005
Nonvisual/Patterns	1.1	1	204	.290	.005

According to Cohen (1988), an eta squared statistic of .01 = small effect size, .06 = moderate effect size, and .14 = large effect size. On the English version of the Grade 3 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to visual questions containing graphs (.254) and nonvisual questions to questions with a geometric figure (.201). A moderate effect size on this same version was found in the comparison of nonvisual questions to all visual questions (.105), nonvisual questions to questions that contain a manipulative image (.120), and nonvisual questions to questions with a visual including a pattern (.076). On the Spanish version of the Grade 3 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to all visual questions (.307), to questions with graphs (.234), to questions with a visual of a geometric figure (.452), and to questions with a visual that can be used as a manipulative (.257). A moderate effect size was found in the comparison of nonvisual questions to questions including a table (.067).

On the English version of the Grade 4 Mathematics TAKS Test, a small effect size was found in the comparison of nonvisual questions to questions with a graph (.029), to questions with a geometric figure (.029), and to questions with an image related to a pattern (.012). On the Spanish version of the Grade 4 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to questions with a graph (.276), and a small effect size was found in the comparison of nonvisual questions to questions with a geometric figure (.046).

The results of this part of the study indicated statistically significant results at the .05 level for all comparisons except for six comparisons overall. The majority of the comparisons that did not show statistically significant results occurred on the Grade 4 Spanish Test. Table 20 summarizes the comparisons that showed statistically significant differences as well as those comparisons that did not show statistically significant differences for the students participating in a two-way dual language immersion environment. For the comparisons that did show a statistically significant difference, the category with the higher mean was also listed. In almost every comparison with a statistically significant difference, the question type with the visual had the higher mean; in only three of the categories with statistically significant differences did the nonvisual questions have the higher mean. Two of those comparisons in which nonvisual questions had the higher mean included the comparison with questions related to a pattern.

Table 20
Statistical Results from Research Question 3 Focused on Visual and Nonvisual Questions for Students Who Participated in a Two-Way Dual Language Immersion Environment

	Statistically Significant Difference	Question Type With a Higher Mean	Not a Statistically Significant Difference
Grade 3 English Test	Nonvisual/All Visual Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric Nonvisual/Manipulatives Nonvisual/Pattern	All Visual Graphs Tables Geometric Manipulatives Nonvisual	
Grade 3 Spanish Test	Nonvisual/All Visual Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric Nonvisual/Manipulatives	All Visual Graphs Tables Geometric Manipulatives	Nonvisual/Pattern
Grade 4 English Test	Nonvisual/All Visual Nonvisual/Graphs Nonvisual/Geometric Nonvisual/Manipulatives Nonvisual/Pattern	All Visual Graphs Geometric Manipulatives Nonvisual	Nonvisual/Tables
Grade 4 Spanish Test	Nonvisual/Graphs Nonvisual/Geometric	Graphs Nonvisual	Nonvisual/All Visual Nonvisual/Tables Nonvisual/Manipulatives Nonvisual/Pattern

Research Question 4: Analyses of Visual and Nonvisual Questions for Students Participated in a Monolingual English Educational Program

For the fourth research question, the same identified questions and analyses from the third research question were conducted for students who participated in a monolingual English program. Multiple one-way ANOVAs were conducted to analyze the effect of question type on the Mathematics TAKS Test for these students. Analyses were conducted for all participants in this setting based on grade level and test language version. Four different comparisons were made for students taking the Mathematics TAKS Test in a monolingual English program including the English version of the Grade 3 Mathematics TAKS Test, Spanish version of the Grade 3 Mathematics TAKS Test, English version of the Grade 4 Mathematics TAKS Test, and Spanish version of the Grade 4 Mathematics TAKS Test. The subsets of questions included nonvisual questions, all questions with a visual, questions containing a visual of a graph, questions containing a visual of a table, questions containing a visual of a geometric figure, questions containing a visual that can be used as a manipulative, and questions containing a visual related to a pattern. Five different assumptions had to be met, including the measurement of the dependent variable on an interval or ratio scale, the use of random sampling, independence of data observations from one another, normal distribution of data from the populations sampled, and similar variabilities of scores from each group (Pallant, 2007). Given that the first three assumptions were met and that the sample size was large enough that a violation of the normal distribution of data would not cause major problems, the researcher interpreted the multivariate statistics provided by SPSS since the sphericity assumption focused on similar variabilities in not required (Pallant, 2007). According to Pallant (2007), the Wilks' Lambda is the most commonly reported statistic used in this type of analysis.

Table 21 lists the breakdown of data by question type, mean, and standard deviation, with question type arranged from highest mean to lowest mean for each version of the test for students enrolled in a monolingual educational program. For the English version of the Grade 3 Mathematics TAKS Test, the subset of visual questions including graphs had the highest mean of correct responses (M = 88.541), and the subset of visual questions including patterns had the lowest mean of correct responses (M = 73.071). For the Spanish version of the Grade 3 Mathematics TAKS Test, the subset of visual questions including geometric figures had the highest mean of correct responses (M = 87.516), and the subset of visual questions including patterns had the lowest mean of correct responses (M = 73.257). For the English version of the Grade 4 Mathematics TAKS Test, the subset of visual questions including graphs had the highest mean of correct responses (M = 87.512), and the subset of visual questions including tables had the lowest mean of correct responses (M = 81.492). For the Spanish version of the Grade 4 Mathematics TAKS Test, the subset of visual questions including graphs had the highest mean of correct responses (M = 85.268), and the subset of visual questions including tables had the lowest mean of correct responses (M = 69.268).

Table 21

Mean Score and Standard Deviation Values for One-Way ANOVAs to Analyze Subset Scores on the Spring 2009 Mathematics TAKS Test for Students in a Monolingual English Educational Program

	Question Type	Mean Score	Standard Deviation
Grade 3:			
English Test	Graphs	88.541	17.935
(N = 1581)	Geometric	88.443	16.186
	Manipulatives	85.218	17.354
	All Visual	84.187	15.035
	Tables	82.269	20.765
	Nonvisual	79.481	19.597
	Patterns	73.071	26.210
Spanish Test	Geometric	87.516	18.403
(N = 263)	Graphs	84.728	20.598
	All Visual	81.214	18.054
	Tables	81.065	21.446
	Manipulatives	80.038	21.170
	Nonvisual	74.115	23.091
	Patterns	73.257	27.298
Grade 4:			
English Test	Graphs	87.512	16.967
(N = 1403)	Geometric	87.491	18.823
	All Visual	84.783	15.252
	Manipulatives	84.740	18.184
	Nonvisual	84.528	17.851
	Patterns	82.419	20.948
	Tables	81.492	27.155
	Graphs	85.268	21.863
Spanish Test	Patterns	78.943	21.319
(N = 205)	All Visual	77.334	19.004
	Nonvisual	77.213	19.237
	Manipulatives	76.634	22.116
	Geometric	72.805	25.511
	Tables	69.268	36.061

Table 22 summarizes each one-way ANOVA used to analyze subset scores on the Spring 2009 Mathematics TAKS Test for students in a monolingual English educational program. A statistically significant difference at the .05 level between nonvisual questions and all visual questions was found on the English version of the Grade 3 Mathematics TAKS Test ($p = .000$) and the Spanish version of the Grade 3 Mathematics TAKS Test ($p = .000$). No statistically significant difference at the .05 level was found when comparing nonvisual questions to all visual questions on the Grade 4 Mathematics TAKS Test for either language. When comparing various subsets of visual questions to nonvisual questions, a statistically significant difference at the .05 level with $p = .000$ was found for all comparisons (nonvisual/graphs, nonvisual/tables, nonvisual/geometric figures, nonvisual/manipulatives, nonvisual/patterns) from English version of the Grade 3 Mathematics TAKS Test. When comparing various subsets of visual questions to nonvisual questions on the Spanish version of the Grade 3 Mathematics TAKS Test, a statistically significant difference at the .05 level was found for all comparisons ($p = .000$) except for nonvisual questions compared to questions with a pattern visual ($p = .602$). When comparing various subsets of visual questions to nonvisual questions on the English version of the Grade 4 Mathematics TAKS Test, a statistically significant difference at the .05 level was found for all comparisons ($p = .000$) except for nonvisual questions compared to questions containing a visual that can be used as a manipulative ($p = .580$).

Table 22
Summaries for One-Way ANOVAs to Analyze Subset Scores on the Spring 2009 Mathematics TAKS Test for Students in a Monolingual English Educational Program

	F	Hypothesis df	Error df	p	Partial Eta Squared
Grade 3 English Test:					
Nonvisual/All Visual	195.6	1	1580	.000	.110
Nonvisual/Graphs	427.9	1	1580	.000	.213
Nonvisual/Tables	37.1	1	1580	.000	.023
Nonvisual/Geometric	417.8	1	1580	.000	.209
Nonvisual/Manipulatives	204.0	1	1580	.000	.114
Nonvisual/Patterns	120.0	1	1580	.000	.071
Grade 3 Spanish Test:					
Nonvisual/All Visual	67.1	1	262	.000	.204
Nonvisual/Graphs	92.5	1	262	.000	.261
Nonvisual/Tables	27.3	1	262	.000	.094
Nonvisual/Geometric	140.0	1	262	.000	.348
Nonvisual/Manipulatives	40.4	1	262	.000	.134
Nonvisual/Patterns	.3	1	262	.602	.001
Grade 4 English Test:					
Nonvisual/All Visual	.7	1	1402	.399	.001
Nonvisual/Graphs	54.6	1	1402	.000	.037
Nonvisual/Tables	25.8	1	1402	.000	.018
Nonvisual/Geometric	29.9	1	1402	.000	.021
Nonvisual/Manipulatives	.3	1	1402	.580	.000
Nonvisual/Patterns	21.7	1	1402	.000	.015
Grade 4 Spanish Test:					
Nonvisual/All Visual	.02	1	204	.881	.000
Nonvisual/Graphs	40.9	1	204	.000	.167
Nonvisual/Tables	13.9	1	204	.000	.064
Nonvisual/Geometric	8.2	1	204	.005	.039
Nonvisual/Manipulatives	.4	1	204	.553	.002
Nonvisual/Patterns	2.0	1	204	.162	.010

When comparing various subsets of visual questions to nonvisual questions on the Spanish version of the Grade 4 Mathematics TAKS Test, a statistically significant difference at the .05 level was found in only three comparisons: nonvisual questions versus questions with a graph ($p = .000$), questions with a table ($p = .000$), and questions with a visual of a geometric figure (p = .005). Each of the other comparisons for this version of the test had no statistically significant difference at the .05 level.

According to Cohen (1988), an eta squared statistic of .01 = small effect size, .06 = moderate effect size, and .14 = large effect size. On the English version of the Grade 3 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to visual questions containing graphs (.213) and nonvisual questions to questions with a geometric figure (.209). A moderate effect size on this same version was found in the comparison of nonvisual questions to all visual questions (.110), to questions that contain a manipulative image (.114), and to questions with a visual including a pattern (.071). On the Spanish version of the Grade 3 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to all visual questions (.204), to questions with graphs (.261), and to questions with a visual of a geometric figure (.348). A moderate effect size on this same version was found in the comparison of nonvisual questions to questions containing a table (.094) and to questions containing an image that can be used as a manipulative (.134).

On the English version of the Grade 4 Mathematics TAKS Test, a small effect size was found in the comparison of nonvisual questions to questions with a graph (.037), to questions with a table (.018), to questions with a geometric figure (.021), and to questions containing an image related to a pattern (.015). On the Spanish version of the Grade 4 Mathematics TAKS Test, a large effect size was found in the comparison of nonvisual questions to questions with a graph (.167). A moderate effect size was found in the comparison of nonvisual questions to questions with a table (.064). A small effect size was found in the comparison of nonvisual questions to questions containing a geometric figure (.039).

The results of this part of the study indicated statistically significant results at the .05 level for all but six comparisons. The comparisons in this part of the study were the same as the comparisons in the part related to Question 3 except these comparisons focused on students in a monolingual English program while Question 3 focused on the students in a two-way dual language immersion program. Table 23 summarizes the comparisons that showed statistically significant differences as well as those that did not show statistically significant differences. For the comparisons that showed a statistically significant difference, the category with the higher mean was also listed. In almost every comparison with a statistically significant difference, the question type with the visual had the higher mean; in only five of the categories with statistically significant differences did the nonvisual questions have the higher mean. Two of those categories in which nonvisual questions had the higher mean included a comparison with questions related to a pattern and questions with a table. The same three comparisons that showed the nonvisual questions to have the higher mean for the two-way dual language immersion students also show nonvisual questions have the higher mean for the monolingual English students.

Table 23
Statistical Results from Research Question 4 Focused on Visual and Nonvisual Questions for Students in a Monolingual English Educational Program

	Statistically Significant Difference	Question Type With a Higher Mean	Not a Statistically Significant Difference
Grade 3 English Test	Nonvisual/All Visual Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric Nonvisual/Manipulatives Nonvisual/Patterns	All Visual Graphs Tables Geometric Manipulatives Nonvisual	
Grade 3 Spanish Test	Nonvisual/All Visual Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric Nonvisual/Manipulatives	All Visual Graphs Tables Geometric Manipulatives	Nonvisual/Patterns
Grade 4 English Test	Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric Nonvisual/Patterns	Graphs Nonvisual Geometric Nonvisual	Nonvisual/Visual Nonvisual/Manipulatives
Grade 4 Spanish Test	Nonvisual/Graphs Nonvisual/Tables Nonvisual/Geometric	Graphs Nonvisual Nonvisual	Nonvisual/All Visual Nonvisual/Manipulatives Nonvisual/Patterns

Research Questions 5: Analyses of Question Type and Group Based on Educational Program

The fifth research question was analyzed using a 2x2 Mixed Between-Within ANOVA with factors of question type (visual and nonvisual) and educational program (two-way dual language and monolingual). Different analyses were conducted utilizing all identified nonvisual questions and the identified subgroups of visual questions. The subsets of questions included: nonvisual questions, all questions with a visual, questions containing a visual of a graph, questions containing a visual of a table, questions containing a visual of a geometric figure, questions containing a visual that can be used as a manipulative, and questions containing a visual related to a pattern. The independent variables included educational program and question type. The educational program was an independent measure (between-subjects factor) while the question type was a repeated measure (within-subjects factor). A 2x2 Mixed Between-Within ANOVA was chosen to analyze the data because of the mix of between- and within-subjects factors. Four different analyses were conducted based on grade level and test version. These included the English version of the Grade 3 Mathematics TAKS Test, Spanish version of the Grade 3 Mathematics TAKS Test, English version of the Grade 4 Mathematics TAKS Test, and Spanish version of the Grade 4 Mathematics TAKS Test. Six different assumptions had to be met, including the measurement of the dependent variable on an interval or ratio scale, the use of random sampling, independence of data observations from one another, normal distribution of data from the populations sampled, similar variabilities of scores from each group, and homogeneity of inter-correlations (Pallant, 2007). Given that the first three assumptions were met and that the sample size was large enough that a violation of the normal distribution of data would not cause major problems, the researcher interpreted the multivariate statistics provided by SPSS since the sphericity assumption focused on similar variabilities in not required (Pallant, 2007). According to Pallant (2007), the Wilks' Lambda is the most commonly reported statistic used in this type of analysis. A Box's M statistic was used to test the assumption of homogeneity of inter-correlations (Pallant, 2007).

Table 24 lists the breakdown of data for Grade 3 by group with a listing of means and rankings for each subgroup of questions. When ranking the means of each question type from highest to lowest on the English version of the test, the rankings were exactly the same for both dual language immersion students and students in a monolingual English program. On the Grade 3 English version of the test, the highest mean score for both two-way immersion students (M = 90.723) and students in a monolingual English program (M = 88.541) was for the subset of visual questions with a graph. The lowest mean score on this same version of the test for two-way immersion students (M = 74.557) and students in a monolingual English program (M = 73.071) was for the subset of visual questions with an image related to a pattern.

When ranking the means of each question type from highest to lowest on the Spanish version of the test, the rankings were very similar with the only interchange between the fourth and fifth ranking of questions with a table and questions with a manipulative. For the two-way dual language immersion students, the questions with a manipulative ranked fourth and the questions with a table ranked fifth. These two rankings were reversed for the students in a monolingual English program. On the Spanish version of the Grade 3 Mathematics TAKS Test, the highest mean score for both two-way immersion students (M = 91.445) and students in a monolingual English program (M = 87.516) was in the subset of visual questions with a geometric figure. The lowest mean score on this same version of the test for two-way immersion students (M = 71.736) and students in a monolingual English program (M = 73.257) was in the subset of visual questions with an image related to a pattern.

Table 24

Student Performance on Nonvisual and Various Subgroups of Visual Questions on the Spring 2009 Grade 3 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Question Type	Mean for Two-Way Students	Ranking for Two-Way Students	Mean for Students In a Monolingual English program	Ranking for Students In a Monolingual English program
English Test:	Nonvisual	81.031	6	79.481	6
	All Visual	85.454	4	84.187	4
	Graphs	90.723	1	88.541	1
	Tables	83.291	5	82.269	5
	Geometric Fig.	89.717	2	88.443	2
	Manipulatives	86.483	3	85.218	3
	Patterns	74.557	7	73.071	7
Spanish Test:	Nonvisual	74.408	6	74.115	6
	All Visual	82.890	3	81.214	3
	Graphs	84.221	2	84.728	2
	Tables	79.316	5	81.065	4
	Geometric	91.445	1	87.516	1
	Manipulatives	82.795	4	80.038	5
	Patterns	71.736	7	73.257	7

Table 25 lists the breakdown of data for Grade 4 by group with a listing of means and rankings for each subgroup of questions. When ranking the means of each question type from highest to lowest on the English version of the test, the rankings were very different. On the English version of the Grade 3 Mathematics TAKS Test, the highest mean score for two-way immersion students (M = 87.812) was for questions with a geometric figure, and the highest mean score for students in a monolingual English program (M = 87.512) was for questions with a graph. The lowest mean score on this same version of the test for two-way immersion students (M = 82.514) was for questions containing an image related to a pattern, and the lowest mean score for students in a monolingual English program (M = 81.492) was for questions with a table.

Table 25

Student Performance on Nonvisual and Various Subgroups of Visual Questions on the Spring 2009 Grade 4 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Question Type	Mean for Two-Way Students	Ranking for Students In a Monolingual English program	Mean for Students In a Monolingual English program	Ranking for Two-Way Students
English Test:	Nonvisual	84.391	5	84.528	5
	All Visual	85.307	4	84.783	3
	Graphs	86.999	2	87.512	1
	Tables	83.583	6	81.492	7
	Geometric Fig.	87.812	1	87.491	2
	Manipulatives	85.652	3	84.740	4
	Patterns	82.514	7	82.419	6
Spanish Test:	Nonvisual	82.265	2	77.213	4
	All Visual	82.108	3	77.334	3
	Graphs	90.829	1	85.268	1
	Tables	78.211	6	69.268	7
	Geometric Fig.	77.927	7	72.805	6
	Manipulatives	81.220	4	76.634	5
	Patterns	81.057	5	78.943	2

When ranking the means of each question type from highest to lowest on the Spanish version of the test, the rankings were alike at the top of the list but varied as the ranking increased. For the two-way dual language immersion students (M = 90.829) and students in a monolingual English program (M = 85.268), the questions with a graph ranked first. For the two-way dual language immersion students (M = 77.927), questions with a geometric figure ranked the lowest, and for the students in a monolingual English program (M = 69.268), questions with a table ranked the lowest.

Table 26 summarizes each mixed between-within ANOVA used to analyze subset scores on the English version of the Spring 2009 Grade 3 Mathematics TAKS Test. The researcher used an ANOVA to compare data from the two-way dual language immersion group and the monolingual education group for nine different comparisons of nonvisual questions to all visual questions and subsets of particular types of visual questions. In the comparison of nonvisual questions to all visual questions, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 3160) = .365, p = .546, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .892, F(1, 3160) = 381.3, p = .000, partial eta squared = .108, with both groups showing a higher performance on questions with a visual (M_{DL} = 85.454, M_{ME} = 84.187) over nonvisual questions (M_{DL} = 81.031, M_{ME} = 79.481) in all areas except the questions that contained a visual related to a pattern [M_{DL} = mean of dual language immersion students and M_{ME} = mean of students in a monolingual English program]. The effect size in this case was considered moderate according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 3160) = 6.421, p = .011, partial eta squared = .002. However, the effect size was considered less than small according to Cohen (1988).

Table 26

Summaries for Mixed Between-Within ANOVAs to Analyze Subset Scores on the English Version of the Spring 2009 Grade 3 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Interaction and Main Effects	Wilks' Lambda	F	p	Partial Eta Squared
English Test:					
Nonvisual/All Visual	Ques Type * Group	1.000	.4	.546	.000
	Question Type	.892	381.3	.000	.108
	Group		6.4	.011	.002
Nonvisual/Graphs	Ques Type * Group	1.000	1.1	.296	.000
	Question Type	.767	960.0	.000	.233
	Group		10.7	.001	.003
Nonvisual/Tables	Ques Type * Group	1.000	.7	.413	.000
	Question Type	.981	61.4	.000	.019
	Group		4.2	.039	.001
Nonvisual/Geometric	Ques Type * Group	1.000	.2	.656	.000
	Question Type	.795	816.2	.000	.205
	Group		6.9	.009	.002
Nonvisual/Manipulatives	Ques Type * Group	1.000	.3	.603	.000
	Question Type	.883	418.3	.000	.117
	Group		5.9	.015	.002
Nonvisual/Patterns					
	Ques Type * Group	1.000	<.1	.938	.000
	Question Type	.927	248.8	.000	.073
	Group		4.9	.028	.002

Note. When the significance value of the Box's Test of Equality of Covariance Matrices is less than .01, the assumption of homogeneity of inter-correlations is violated (Pallant, 2007) and indicated following the listed comparison.

In the comparison of nonvisual questions to visual questions containing a graph on the English version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, $F(1, 3160) = 1.092$, $p = .296$, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .767, $F(1, 3160) = 960$, $p = .000$, partial eta squared = .233, with both groups showing a higher performance on questions with a visual containing a graph ($M_{DL} = 90.723$, $M_{ME} = 88.541$) over nonvisual questions ($M_{DL} = 81.031$, $M_{ME} = 79.481$). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was also significant, $F(1, 3160) = 10.685$, $p = .001$, partial eta squared = .003. However, the effect size was considered less than small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a table on the English version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, $F(1, 3160) = .670$, $p = .413$, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .981, $F(1, 3160) = 61.414$, $p = .000$, partial eta squared = .019, with both groups showing a higher performance on questions with a visual containing a table ($M_{DL} = 83.291$, $M_{ME} = 82.269$) over nonvisual questions ($M_{DL} = 81.031$, $M_{ME} = 79.481$). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was also significant, $F(1, 3160) = 4.247$, $p = .039$, partial eta squared = .001. However, the effect size was considered less than small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a geometric figure on the English version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 3160) = .199, p = .656, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .795, F(1, 3160) = 816.2, p = .000, partial eta squared = .205, with both groups showing a higher performance on questions with a visual containing a geometric figure (M_{DL} = 89.717, M_{ME} = 88.443) over nonvisual questions (M_{DL} = 81.031, M_{ME} = 79.481). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 3160) = 6.863, p = .009, partial eta squared = .002. However, the effect size was considered less than small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing an image that can be used as a manipulative on the English version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 3160) = .271, p = .603, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .883, F(1, 3160) = 418.3, p = .000, partial eta squared = .117 with both groups showing a higher performance on questions with a visual containing an image that can be used as a manipulative (M_{DL} = 86.483, M_{ME} = 85.218) over nonvisual questions (M_{DL} = 81.031, M_{ME} = 79.481). The effect size in this case was considered moderate according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 3160) = 5.902, p = .015, partial eta squared = .002. However, the effect size was considered less than small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing an image related to a pattern on the English version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 3160) = .006, p = .938, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .927, F(1, 3160) = 248.9, p = .000, partial eta squared = .073 with both groups showing a higher performance on questions without a visual (M_{DL} = 81.031, M_{ME} = 79.481) over questions with a visual containing an image related to a pattern (M_{DL} = 74.557, M_{ME} = 73.071). The effect size in this case was considered moderate according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 3160) = 4.855, p = .028, partial eta squared = .002. However, the effect size was considered less than small according to Cohen (1988).

Table 27 summarizes each mixed between-within ANOVA used to analyze subset scores on the Spanish version of the Spring 2009 Grade 3 Mathematics TAKS Test. The researcher used an ANOVA to compare data from the dual language immersion group and the monolingual education group for nine different comparisons of nonvisual questions to all visual questions and subsets of particular types of visual questions. In the comparison of nonvisual questions to all visual questions, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .997, F(1, 524) = 1.397, p = .238, partial eta squared = .003. There was a main effect for question type, Wilks Lambda = .747, F(1, 524) = 177.2, p = .000, partial eta squared = .253, with both groups showing a higher performance on questions with a visual (M_{DL} = 82.890, M_{ME} = 81.214) over nonvisual questions (M_{DL} = 74.408, M_{ME} = 74.115) in all areas except for the questions that contained a visual related to a pattern.

Table 27
Summaries for Mixed Between-Within ANOVAs to Analyze Subset Scores on the Spanish Version of the Spring 2009 Grade 3 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Interaction and Main Effects	Wilks' Lambda	F	p	Partial Eta Squared
Spanish Test:					
Nonvisual/All Visual	Ques Type * Group	.997	1.4	.238	.003
	Question Type	.747	177.2	.000	.253
	Group		.4	.529	.001
Nonvisual/Graphs	Ques Type * Group	.999	.3	.608	.001
	Question Type	.753	172.2	.000	.247
	Group		<.1	.948	.000
Nonvisual/Tables	Ques Type * Group	.997	1.4	.242	.003
	Question Type	.919	46.2	.000	.081
	Group		.2	.661	.000
Nonvisual/Geometric (Box's Test not met)	Ques Type * Group	.990	5.0	.025	.010
	Question Type	.598	352.8	.000	.402
	Group		2.1	.147	.004
Nonvisual/Manipulatives (Box's Test not met)	Ques Type * Group	.993	3.7	.055	.007
	Question Type	.808	124.4	.000	.192
	Group		.9	.355	.002
Nonvisual/Patterns	Ques Type * Group	.999	.6	.440	.001
	Question Type	.996	2.3	.133	.004
	Group		.1	.741	.000

Note. When the significance value of the Box's Test of Equality of Covariance Matrices is less than .01, the assumption of homogeneity of inter-correlations is violated (Pallant, 2007) and indicated following the listed comparison.

The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 524) = .396, p = .529, partial eta squared = .001. However, the effect size was considered less than small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a graph on the Spanish version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .999, F(1, 524) = .264, p = .608, partial eta squared = .001. There was a main effect for question type, Wilks Lambda = .753, F(1, 524) = 172.2, p = .000, partial eta squared = .247, with both groups showing a higher performance on questions with a visual containing a graph (M_{DL} = 84.221, M_{ME} = 84.728) over nonvisual questions (M_{DL} = 74.408, M_{ME} = 74.115). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was not significant, F(1, 524) = .004, p = .948, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing a table on the Spanish version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .997, F(1, 524) = 1.369, p = .242, partial eta squared = .003. There was a main effect for question type, Wilks Lambda = .919, F(1, 524) = 46.191, p = .000, partial eta squared = .081, with both groups showing a higher performance on questions with a visual containing a table (M_{DL} = 79.316, M_{ME} = 81.065) over nonvisual questions (M_{DL} = 74.408, M_{ME} = 74.115). The effect size in this case was considered moderate according to Cohen

(1988). The main effect comparing the two groups was not significant, $F(1, 524) = .192$, $p = .661$, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing a geometric figure on the Spanish version of the Grade 3 Mathematics TAKS Test, there was a significant interaction at the .05 level between question type and group, Wilks Lambda = .990, $F(1, 524) = 5.036$, $p = .025$, partial eta squared = .010. There was a main effect for question type, Wilks Lambda = .598, $F(1, 524) = 352.8$, $p = .000$, partial eta squared = .402, with both groups showing a higher performance on questions with a visual containing a geometric figure ($M_{DL} = 91.445$, $M_{ME} = 87.516$) over nonvisual questions ($M_{DL} = 74.408$, $M_{ME} = 74.115$). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was not significant, $F(1, 524) = 2.114$, $p = .147$, partial eta squared = .004.

In the comparison of nonvisual questions to visual questions containing an image that can be used as a manipulative on the Spanish version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .993, $F(1, 524) = 3.689$, $p = .055$, partial eta squared = .007. There was a main effect for question type, Wilks Lambda = .808, $F(1, 524) = 124.4$, $p = .000$, partial eta squared = .192, with both groups showing a higher performance on questions with a visual containing an image that can be used as a manipulative ($M_{DL} = 82.795$, $M_{ME} = 80.038$) over nonvisual questions ($M_{DL} = 74.408$, $M_{ME} = 74.115$). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was not significant, $F(1, 524) = .857$, $p = .355$, partial eta squared = .002.

In the comparison of nonvisual questions to visual questions containing an image related to a pattern on the Spanish version of the Grade 3 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .999, $F(1, 524) = .597$, $p = .440$, partial eta squared = .001. There was no main effect for question type, Wilks Lambda = .996, $F(1, 524) = 2.261$, $p = .133$, partial eta squared = .004, with both groups showing a higher performance on questions without a visual ($M_{DL} = 74.408$, $M_{ME} = 74.115$) over questions with a visual containing an image related to a pattern ($M_{DL} = 71.736$, $M_{ME} = 73.257$). The main effect comparing the two groups was also not significant, $F(1, 524) = .109$, $p = .741$, partial eta squared = .000.

Table 28 summarizes each mixed between-within ANOVA used to analyze subset scores on the English version of the Spring 2009 Grade 4 Mathematics TAKS Test. The researcher used an ANOVA to compare data from the dual language immersion group and the monolingual education group for nine different comparisons of nonvisual questions to all visual questions and subsets of particular types of visual questions. In the comparison of nonvisual questions to all visual questions, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .999, $F(1, 2804) = 2.422$, $p = .120$, partial eta squared = .001. There was a main effect for question type, Wilks Lambda = .997, $F(1, 2804) = 7.580$, $p = .006$, partial eta squared = .003, with both groups showing a higher performance on questions with a visual ($M_{DL} = 85.307$, $M_{ME} = 84.783$) over nonvisual questions ($M_{DL} = 83.391$, $M_{ME} =$

84.528) in all areas except for the questions that contained a table and those questions that contained a visual related to a pattern.

Table 28

Summaries for Mixed Between-Within ANOVAs to Analyze Subset Scores on the English Version of the Spring 2009 Grade 4 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Interaction and Main Effects	Wilks' Lambda	F	p	Partial Eta Squared
English Test:					
Nonvisual/All Visual	Ques Type * Group	.999	2.4	.120	.001
	Question Type	.997	7.6	.006	.003
	Group		.1	.740	.000
Nonvisual/Graphs	Ques Type * Group	1.000	.4	.512	.000
	Question Type	.967	95.3	.000	.033
	Group		.3	.590	.000
Nonvisual/Tables	Ques Type * Group	.997	7.1	.008	.003
	Question Type	.993	21.2	.000	.007
	Group		1.7	.187	.001
Nonvisual/Geometric	Ques Type * Group	1.000	.4	.546	.000
	Question Type	.975	70.9	.000	.025
	Group		<.1	.873	.000
Nonvisual/Manipulatives	Ques Type * Group	.999	3.8	.052	.001
	Question Type	.997	7.4	.006	.003
	Group		.4	.528	.000
Nonvisual/Patterns					
	Ques Type * Group	1.000	.1	.716	.000
	Question Type	.986	38.9	.000	.014
	Group		<.1	.974	.000

Note. When the significance value of the Box's Test of Equality of Covariance Matrices is less than .01, the assumption of homogeneity of inter-correlations is violated (Pallant, 2007) and indicated following the listed comparison.

The effect size in this case was considered less than small according to Cohen (1988). The main effect comparing the two groups was not significant, $F(1, 2804) = .110$, $p = .740$, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing a graph on the English version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, $F(1, 2804) = .430$, $p = .512$, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .967, $F(1, 2804) = 95.280$, $p = .000$, partial eta squared = .033, with both groups showing a higher performance on questions with a visual containing a graph ($M_{DL} = 86.999$, $M_{ME} = 87.512$) over nonvisual questions ($M_{DL} = 84.391$, $M_{ME} = 84.528$). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was not significant, $F(1, 2804) = .290$, $p = .590$, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing a table on the English version of the Grade 4 Mathematics TAKS Test, there was a significant interaction between question type and group at the .05 level, Wilks Lambda = .997, $F(1, 2804) = 7.116$, $p = .008$, partial eta squared = .003. The monolingual education group ($M_{ME} = 84.528$) showed a higher mean on nonvisual questions than the dual language immersion group ($M_{DL} = 84.391$) while the dual language immersion group ($M_{DL} = 83.583$) showed a higher mean on the visual questions with a table than the monolingual education group ($M_{ME} = 81.492$). The effect size in this case was considered to be less than small according to Cohen (1988). There was a main effect for question type, Wilks

Lambda = .993, F(1, 2804) = 21.177, p = .000, partial eta squared = .007, with both groups showing a lower performance on questions with a visual containing a table (M_{DL} = 83.583, M_{ME} = 81.492) compared to nonvisual questions (M_{DL} = 84.391, M_{ME} = 84.528). The effect size in this case was considered less than small according to Cohen (1988). The main effect comparing the two groups was not significant, F(1, 2804) = 1.738, p = .187, partial eta squared = .001.

In the comparison of nonvisual questions to visual questions containing a geometric figure on the English version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 2804) = .365, p = .546, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .975, F(1, 2804) = 70.884, p = .000, partial eta squared = .025, with both groups showing a higher performance on questions with a visual containing a geometric figure (M_{DL} = 87.812, M_{ME} = 87.491) over nonvisual questions (M_{DL} = 84.391, M_{ME} = 84.528). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was not significant, F(1, 2804) = .026, p = .873, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing an image that can be used as a manipulative on the English version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .999, F(1, 2804) = 3.775, p = .052, partial eta squared = .001. There was a main effect for question type, Wilks Lambda = .997, F(1, 2804) = 7.436, p = .006, partial eta squared = .003, with both groups showing a higher performance on questions with a visual containing an image that can be used as a manipulative (M_{DL} = 85.652, M_{ME} = 84.740) over nonvisual questions (M_{DL} = 84.391, M_{ME} = 84.528). The effect size in this case was considered less than small according to Cohen (1988). The main effect comparing the two groups was not significant, F(1, 2804) = .398, p = .528, partial eta squared = .000.

In the comparison of nonvisual questions to visual questions containing an image related to a pattern on the English version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 2804) = .132, p = .716, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .986, F(1, 2804) = 38.937, p = .000, partial eta squared = .014, with both groups showing a higher performance on questions without a visual (M_{DL} = 84.391, M_{ME} = 84.528) over questions with a visual containing an image related to a pattern (M_{DL} = 82.514, M_{ME} = 82.419). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was not significant, F(1, 2804) = .001, p = .974, partial eta squared = .000.

Table 29 summarizes each mixed between-within ANOVA used to analyze subset scores on the Spanish version of the Spring 2009 Grade 4 Mathematics TAKS Test. The researcher used an ANOVA to compare data from the dual language immersion group and the monolingual education group for nine different comparisons of nonvisual questions to all visual questions and subsets of particular types of visual questions.

Table 29

Summaries for Mixed Between-Within ANOVAs to Analyze Subset Scores on the Spanish Version of the Spring 2009 Grade 4 Mathematics TAKS Test for Two-Way Dual Language Immersion Students and Students in a Monolingual English Educational Program

	Interaction and Main Effects	Wilks' Lambda	F	p	Partial Eta Squared
Spanish Test:					
Nonvisual/All Visual	Ques Type * Group	1.000	<.1	.803	.000
(Box's Test not met)	Question Type	1.000	<.1	.975	.000
	Group		9.6	.002	.023
Nonvisual/Graphs	Ques Type * Group	1.000	.1	.749	.000
(Box's Test not met)	Question Type	.789	109.3	.000	.211
	Group		11.5	.001	.027
Nonvisual/Tables	Ques Type * Group	.996	1.7	.190	.004
(Box's Test not met)	Question Type	.961	16.4	.000	.039
	Group		10.1	.002	.024
Nonvisual/Geometric Fig.	Ques Type * Group	1.000	<.1	.973	.000
(Box's Test not met)	Question Type	.958	17.8	.000	.042
	Group		8.1	.005	.020
Nonvisual/Manipulatives	Ques Type * Group	1.000	.1	.738	.000
(Box's Test not met)	Question Type	.997	1.4	.246	.003
	Group		7.8	.006	.019
Nonvisual/Patterns	Ques Type * Group	.993	3.1	.081	.007
(Box's Test not met)	Question Type	1.000	.1	.756	.000
	Group		5.0	.025	.012

Note. When the significance value of the Box's Test of Equality of Covariance Matrices is less than .01, the assumption of homogeneity of inter-correlations is violated (Pallant, 2007) and indicated following the listed comparison.

In the comparison of nonvisual questions to all visual questions, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 408) = .062, p = .803, partial eta squared = .000. There was not a main effect for question type, Wilks Lambda = 1.000, F(1, 408) = .001, p = .975, partial eta squared = .000. The main effect comparing the two groups was significant, F(1,408) = 9.605, p = .002, partial eta squared = .023. The dual language immersion students showed a higher mean on the nonvisual questions (M_{DL} = 82.265) compared to the visual questions (M_{DL} = 82.108) while the students in a monolingual English program showed a higher mean on the visual questions (M_{ME} = 77.334) compared to the nonvisual questions (M_{ME} = 77.213). The effect size was considered small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a graph on the Spanish version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 408) = .102, p = .749, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .789, F(1, 408) = 109.3, p = .000, partial eta squared = .211, with both groups showing a higher performance on questions with a visual containing a graph (M_{DL} = 90.829, M_{ME} = 85.268) over nonvisual questions (M_{DL} = 82.265, M_{ME} = 77.213). The effect size in this case was considered large according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 408) = 11.500, p = .001, partial eta squared = .027. However, the effect size in this case was considered small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a table on the Spanish version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .996, F(1, 408) = 1.726, p = .190, partial eta squared = .004. There was a main effect for question type, Wilks Lambda = .961, F(1, 408) = 16.412, p = .000, partial eta squared = .039, with both groups showing a lower performance on questions with a visual containing a table (M_{DL} = 78.211, M_{ME} = 69.268) compared to nonvisual questions (M_{DL} = 82.265, M_{ME} = 77.213). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 408) = 10.113, p = .002, partial eta squared = .024. The effect size was considered as small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing a geometric figure on the Spanish version of the Grade 4 Mathematics TAKS Test, there was not a significant interaction at the .05 level between question type and group, Wilks Lambda = 1.000, F(1, 408) = .001, p = .973, partial eta squared = .000. There was a main effect for question type, Wilks Lambda = .958, F(1, 408) = 17.837, p = .000, partial eta squared = .042, with both groups showing a lower performance on questions with a visual containing a geometric figure (M_{DL} = 77.927, M_{ME} = 72.805) compared to nonvisual questions (M_{DL} = 82.265, M_{ME} = 77.213). The effect size in this case was considered small according to Cohen (1988). The main effect comparing the two groups was also significant, F(1, 408) = 8.143, p = .005, partial eta squared = .020. The effect size was small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing an image that can be used as a manipulative on the Spanish version of the Grade 4 Mathematics

TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = 1.000, F(1, 408) = .112, p = .738, partial eta squared = .000. There was not a main effect for question type, Wilks Lambda = .997, F(1, 408) = 1.350, p = .246, partial eta squared = .003. The main effect comparing the two groups was significant F(1, 408) = 7.752, p = .006, partial eta squared = .019 with both groups showing a lower performance on questions with a visual containing an image that can be used as a manipulative (M_{DL} = 81.220, M_{ME} = 76.634) compared to nonvisual questions (M_{DL} = 82.265, M_{ME} = 77.213). The means for the dual language students are significantly higher in both cases. The effect size in this case was considered small according to Cohen (1988).

In the comparison of nonvisual questions to visual questions containing an image related to a pattern on the Spanish version of the Grade 4 Mathematics TAKS Test, there was no significant interaction between question type and group at the .05 level, Wilks Lambda = .993, F(1, 408) = 3.067, p = .081, partial eta squared = .007. There was no main effect for question type, Wilks Lambda = 1.000, F(1, 408) = .097, p = .756, partial eta squared = .000. The main effect comparing the two groups was also significant, F(1, 408) = 5.036, p = .025, partial eta squared = .012. The means on the questions with a visual containing an image related to a pattern (M_{DL} = 81.057, M_{ME} = 78.943) were smaller than the means on questions without a visual (M_{DL} = 82.265, M_{ME} = 77.213).

Table 30 summarizes the interaction effect and the main effects for each comparison. The results from this research question indicated that there was no interaction effect between question type and group most of the time. The main effect of question type occurred frequently with visual questions having the higher mean more often than nonvisual questions.

Table 30

Statistical Results from Research Question 5 Focused on an Interaction Effect Between Question Type and Group and Main Effects of Question Type and Group

	Question Types	Interaction Effect (Quest Type * Group)	Question Type Effect	Group Effect
Grade 3 English Test	Nonvisual/All Visual		✓	✓
	Nonvisual/Graphs		✓	✓
	Nonvisual/Tables		✓	✓
	Nonvisual/Geometric		✓	✓
	Nonvisual/Manipulatives		✓	✓
	Nonvisual/Pattern		✓	✓
Grade 3 Spanish Test	Nonvisual/All Visual		✓	
	Nonvisual/Graphs		✓	
	Nonvisual/Tables		✓	
	Nonvisual/Geometric	✓	✓	
	Nonvisual/Manipulatives		✓	
	Nonvisual/Pattern			
Grade 4 English Test	Nonvisual/All Visual		✓	
	Nonvisual/Graphs		✓	
	Nonvisual/Tables	✓	✓	
	Nonvisual/Geometric		✓	
	Nonvisual/Manipulatives		✓	
	Nonvisual/Pattern		✓	
Grade 4 Spanish Test	Nonvisual/All Visual			✓
	Nonvisual/Graphs		✓	✓
	Nonvisual/Tables		✓	✓
	Nonvisual/Geometric		✓	✓
	Nonvisual/Manipulatives			✓
	Nonvisual/Pattern			✓

Note. The symbol ✓ indicates that the effect did occur at a statistically significant level.

Differences in visual questions compared to nonvisual questions do appear for students in a monolingual English program, but a few of those differences are not statistically significant. The students who took the Spanish version of the Grade 4 Mathematics TAKS Test had the smallest number of statistically significant differences in these types of questions. The main effect of group occurred more often on the Grade 3 Mathematics TAKS Test than on the Grade 4 Mathematics TAKS Test. On the Grade 3 Mathematics TAKS Test in both English and Spanish, two-way dual language immersion students produced a higher mean most of the time. While the main effect of group was statistically significant in almost all areas on the Grade 4 Spanish Mathematics TAKS Test, group was not a factor on the Grade 4 English Mathematics TAKS Test. On the Grade 4 Mathematics TAKS Test in both English and Spanish, two-way dual language immersion students produced a higher mean most of the time.

Summary of Findings

Two-way dual language immersion programs have not been found to hinder student performance, even though students are learning two different languages with variability in mathematics instruction among programs. Differences in scaled scores did not appear at a statistically significant level except on the Spanish version of the Grade 4 Mathematics TAKS Test for this study. Two-way dual language immersion programs are producing statistically higher scaled scores for fourth-grade students taking the Spanish version of the Mathematics TAKS Test. The positive aspect of the lack of statistically significant differences in the other areas of scaled scores is that two-way dual language immersion programs are not producing lower scaled scores as a result of instruction in two different languages.

Students from two-way dual language immersion programs are scoring higher on subsets of nonvisual and visual questions, with statistically significant differences when compared to students in a monolingual English program on the English version of the Grade 3 Mathematics TAKS Test and the Spanish version of the Grade 4 Mathematics TAKS Test. Thus, visuals in the instructional environment for two-way dual language immersion students seem to be offering some advantages in these areas over those students in a monolingual English program. Although few statistically significant results were reported between the two groups of students on the Spanish version of the Grade 3 Mathematics TAKS Test and the English version of the Grade 4 Mathematics TAKS Test, the positive aspect is that two-way dual language immersion programs are not producing lower percentages of correct responses in these areas as a result of the instruction in two different languages.

Visuals are making a difference in student performance on the Grade 3 and Grade 4 Mathematics TAKS Tests for two-way dual language immersion students. A higher performance was shown on most subsets of visual questions in this study. In particular, this study indicates that visuals that include a graph showed the highest level of achievement for two-way dual language immersion students. Questions with a geometric image and questions with a manipulative were the second highest types of questions that showed a high level of achievement.

Visuals are also making a difference in student performance on the Grade 3 and Grade 4 Mathematics TAKS Tests for students in a monolingual English program. A higher performance was shown on most subsets of visual questions in this study. In particular, this study indicates that visuals that include a graph showed the highest level of achievement for students in a monolingual English program. The category of questions with a geometric image showed the second highest level of achievement.

Although scaled scores were statistically higher, students who took the Spanish version of the Grade 4 Mathematics TAKS Test had the smallest number of statistically significant differences between nonvisual and visual questions. When evaluating the main effect of group on the comparison of nonvisual questions to all visual questions and various subsets of visual questions, there is a main effect for the group with two-way dual language immersion students producing higher means most of the time. This main effect for group occurred more often on the Grade 3 test than on the Grade 4 test.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

Two-way dual language immersion programs are increasing in number as a result of a growing population of native Spanish-speaking students in America's public schools. The researcher identified the use of visuals as a prevalent instructional tool through a series of observations and interviews in a dual language environment. Since the Mathematics TAKS Test contains several questions with visuals, interest arose in the performance of two-way dual language immersion students compared to students in a monolingual English program on questions with a visual, and led to this study. Research exploring the performance of two-way dual language immersion students and students in a monolingual English program on the Mathematics TAKS Test in general, and more specifically on questions with a visual, can provide valuable information to current and newly developing dual language programs as well as to the educational environment in general.

This chapter provides a review of the purpose of the study with research questions restated to focus the discussion of the results. Conclusions and implications based on the research results are presented in separate sections based on each individual research question. The conclusion of the chapter provides a discussion of the implications and recommendations for theory and practice followed by a discussion of the limitations of the study and recommendations for future research.

Purpose of the Study

The purpose of this study was to answer several questions focused on the overall scaled scores and percentages of correct responses on subsets of questions of two-way dual language immersion students who have taken the English or Spanish version of the Grade 3 or Grade 4 Mathematics Texas Assessment of Knowledge and Skills (TAKS) Test in the state of Texas. More specifically, this study sought to determine if students in a two-way dual language immersion program had some aspect of their instructional environment that produced a higher performance in mathematics overall and on mathematics questions with certain types of visual prompts compared to questions that did not have a visual prompt. This study also sought to determine if question type and instructional environment had main effects or an interaction effect on the Grade 3 or Grade 4 Mathematics TAKS Test.

Conclusions and Implications from Research Question 1: Scaled Score Differences

The first goal of this study was to investigate the differences in scaled scores on the Mathematics TAKS Test for two-way dual language immersion students and students in a monolingual English program on the English and Spanish versions of the Grade 3 and Grade 4 TAKS Tests. The results of this part of the study on the scaled scores did not align completely with previous research results in which elementary students in bilingual programs have higher mathematics scores compared to students not enrolled in an immersion program (Egan, 2007; Dow, 2008; Medrano, 1988; Lambert et al., 1993).

A statistically significant difference at the .05 level in scaled scores was found only between the two-way dual language immersion students (M = 2357.59, SD = 236.873) and students in a monolingual English program (M = 2305.23, SD = 287.630) for the Spanish version of the Grade 4 Mathematics TAKS Test: $F(1,408) = 4.047$, $p = .045$.

While descriptive statistics suggest that two-way dual language immersion students had a higher mean than monolingual English students on the English version of the Grade 3 Mathematics TAKS Test and the Grade 4 Mathematics TAKS Test, the difference in means was not statistically significant for this study. Students in a monolingual English program had a higher mean than two-way dual language immersion students on the Spanish version of the Grade 3 Mathematics TAKS Test, but again, this difference was not statistically significant.

The conclusions from this research question implied that students in a two-way dual language immersion program are achieving scaled scores that are comparable to students in a monolingual English program. Any concerns that educators or parents may have about mathematics achievement suffering as a result of the learning of a second language or the variability in mathematics instruction that may occur in a two-way dual language immersion program are not validated by this study. No evidence has been found to show that the dual language immersion program affects mathematics achievement overall on the Mathematics TAKS Test for the third- and fourth-grade levels.

Conclusions and Implications from Research Question 2: Comparing Percentages of Correct Responses on Nonvisual Questions and Various Categories of Visual Questions

The second goal of this study was to investigate the difference in performance of students in a two-way dual language immersion program and students in a monolingual English educational program on nonvisual questions and on various categories of visual questions. A comparison of two-way dual language immersion students and students in a monolingual English program was conducted on both the English and Spanish versions of the Grade 3 and Grade 4 Mathematics TAKS Tests in each of the following categories: nonvisual, visual, graphs, tables, geometric figures, manipulatives, and patterns. Most of the results from the Grade 3 English Mathematics TAKS Test and the Grade 4 Spanish Mathematics TAKS Test for this part of the study did align with previous research results in which elementary students in bilingual programs have higher mathematics scores compared to students not enrolled in a bilingual program (Egan, 2007; Dow, 2008; Medrano, 1988; Lambert et al., 1993).

A statistically significant difference at the .05 level was found in 13 of the 28 comparisons. Most of those statistically significant differences occurred on the Grade 3 English Mathematics TAKS Test (5 of the 7 comparisons) and the Grade 4 Spanish Mathematics TAKS Test (6 of the 7 comparisons). The Grade 3 Spanish Mathematics Test and the Grade 4 English Mathematics Test only had statistically significant differences in one comparison (geometric for Grade 3 Spanish and tables for Grade 4 English).

The conclusions from this research question implied that differences in the performance of students in various categories of questions do appear, and when they appear with statistically significant results at the .05 level, the two-way dual language immersion students have the higher mean than the students in a monolingual English program. In the comparisons in which the students in a monolingual English program displayed a higher mean, the differences in means between the two groups were not statistically significant. Results of this part of the study indicated a statistically significant difference that mainly occurred in percentages of correct responses on the Grade 3 English Mathematics TAKS Test and the Grade 4 Spanish Mathematics TAKS Test. Thus, the number of statistically significant differences in results decreased from the third to the fourth-grade level for scores on the English version of the Spring 2009 Mathematics TAKS Test, and these results increased from third to the fourth-grade level for scores on the Spanish version of the Spring 2009 Mathematics TAKS Test.

Several possible conjectures can be made based on the results listed above. With the Grade 3 English version of the test having statistically significant differences in all but two areas (tables and patterns) and the Grade 4 English version of the test having only one statistically significant difference (tables), the researcher makes a conjecture that as students progress from the third to the fourth grade, schools require more native Spanish speakers to take the TAKS test in English instead of Spanish. These student scores may possibly be lowering the performance of the two-way dual language immersion group since these Spanish speakers may not feel as comfortable or perform as well on a test written in English. Another possibility is that the dual language immersion students are beginning to show a lag at this level since writing is being tested for the first time during fourth grade and a large amount of time is being spent on writing during the English instructional time. This leaves less time for mathematics since the second language is also taught during half of the instructional time.

With the Grade 4 Spanish version of the test having statistically significant differences in all but one area (patterns) and the Grade 3 Spanish version of the test having statistically significant differences in only one area (geometric images), the researcher makes a conjecture that the large number of statistically significant differences are occurring at the fourth-grade level because students in the two-way dual language immersion group are receiving half of their instruction in Spanish and monolingual education speakers do not receive any instruction in Spanish. Students who are taking the Spanish version of the Mathematics TAKS Test at the fourth-grade level of not fluent enough in English to take the English version of this test. The two-way dual language Spanish-speaking students may be showing higher academic achievement in mathematics since they receive English and Spanish instruction at school while monolingual English students only receive Spanish instruction at school.

Research results indicate that the visual category of patterns is the one area where a statistically significant difference never occurs at the Grade 3 and Grade 4 levels. In an examination of the TEKS that are included in Appendix C for these grade levels, patterns are included with a large emphasis on the patterns of fact families. However, questions on the TAKS Test require more analysis and algebraic thought by the student.

Thus, this higher level of thinking for this type of question might offer a possible explanation for the result of no significant difference in both grade levels.

The category of geometric images is the one area where a statistically significant difference occurred most often at the Grade 3 and Grade 4 levels. In an examination of the TEKS that are included in Appendix C for these grade levels, an emphasis on visuals in Geometry is not apparent. While the TEKS do stress identification and descriptions of geometric objects, the exposure of students to visuals in geometry may vary by educational program.

Conclusions and Implications from Research Question 3: Visual and Nonvisual Questions for Students Who Participated in a Two-Way Dual Language Immersion Environment

The third goal of this study was to investigate the difference in performance for students in a two-way dual language immersion program on questions that did not contain a visual compared to questions that did contain a visual. A comparison of nonvisual questions to all visual questions overall was conducted as well as separate comparisons for nonvisual questions and subsets of certain types of visual including graphs, tables, geometric figures, manipulatives, and patterns.

The results from this research question indicated that differences in visual questions compared to nonvisual questions do appear for students in a two-way dual language immersion program. Only six comparisons did not show a statistically significant difference at the .05 level, and four of these were on the Grade 4 Spanish

Test. One possible conjecture that might explain why the Grade 3 English Test, Grade 3 Spanish Test, and Grade 4 English Test mostly show statistically significant results while the Grade 4 Spanish Test does not would center on the idea that the students taking the Grade 4 Spanish Test are fluent in Spanish but not fluent enough in English to be able to take the TAKS Test in the English language by Grade 4. Thus, these students are possibly struggling with the addition of the second language which may be producing a lag effect in other subjects such as mathematics. The weakness in the English language may also indicate weaknesses in interpreting and understanding visuals presented with the problems since these students did better overall on the nonvisual questions.

In the comparisons that showed a statistically significant difference, the category of visuals had the higher mean most of the time (15 out of 18). Thus, students in a two-way dual language immersion program are performing better on questions with a visual than on questions without some type of visual. The importance of the inclusion of visuals in this type of educational program should be noted and included in the instructional design of a two-way dual language immersion program. In particular, questions that contain a visual of a graph not only showed a statistically significant difference when compared to nonvisual questions for every version of the test in this study, but the visual question with the graph had the higher mean in every comparison. Thus, a visual of a graph appears to be important for the instructional design of a two-way dual language immersion program. Questions with a geometric image and questions with a manipulative were the second most common types showing a higher mean at a statistically significant level when compared to questions without a visual. Therefore, educators should also include these types of visuals in the instructional design of a two-way dual language immersion program, and researchers should try to gain an understanding about why patterns and tables appear to show less of a difference.

Conclusions and Implications from Research Question 4: Visual and Nonvisual Questions for Students Who Participated in a Monolingual English Educational Program

The fourth goal of this study was to investigate the difference in performance for students who participated in a monolingual English educational program on questions that did not contain a visual compared to questions that did contain a visual. A comparison of nonvisual questions to all visual questions overall was conducted as well as separate comparisons for nonvisual questions and subsets of certain types of visuals including graphs, tables, geometric figures, manipulatives, and patterns.

The results of this part of the study indicated statistically significant results at the .05 level for all comparisons except for six comparisons overall. Five of these six comparisons were on the Grade 4 Test. The comparisons in this part of the study were the same as the comparisons in the part related to Question 3, except these comparisons focused on students in a monolingual English program while Question 3 focused on the two-way dual language immersion students.

The results from this research question indicated that differences in visual questions compared to nonvisual questions do appear for students in a monolingual

English program, but a few of those differences are not statistically significant. The students who took the Spanish version of the Grade 4 Mathematics TAKS Test had the smallest number of statistically significant differences in these types of questions. In general, questions with a visual do not seem to have as much of an effect on student performance at Grade 4. One possible explanation could be that the Grade 4 TEKS focus more on the application of operations and skills with problem solving while the Grade 3 TEKS focus on mathematical facts and computations. The Grade 3 and Grade 4 TEKS are included in Appendix C. Another possible explanation for visuals not having much effect on student performance in Grade 4 could be a result of students being more fluent in the English language at this level and less dependent on visuals to answer mathematics questions. Students who participate in a monolingual English program are spending their entire time receiving instruction in English and are not having to split their instructional time between two languages. Since more significant differences occur at Grade 3 with visual questions having the higher mean in all but one area, students in Grade 3 seem to be more dependent and efficient in working mathematics questions that contain a visual. Although they are receiving English instruction throughout the entire instructional day, they perhaps have not reached a high level of fluency with the language or with the language as part of a mathematics problem.

In the comparisons that showed a statistically significant difference, the category of visuals had the higher mean most of the time (13 out of 18). Thus, students in a monolingual English program are performing better on questions with a visual than on questions without some type of visual. The importance of the inclusion of visuals in this type of educational program should be noted and included in the instructional design of a monolingual English program. In particular, questions that contain a visual of a graph not only showed a statistically significant difference when compared to nonvisual questions for every version of the test in this study, but the visual question with the graph had the higher mean in every comparison. Thus, a visual of a graph appears to be important for the instructional design of a monolingual English program. The question type with a geometric image was the second most common type showing a higher mean at a statistically significant level when compared to questions without a visual. Therefore, educators should also include these types of visuals in the instructional design of a monolingual English program, and researchers should try to gain an understanding about why questions with patterns and manipulatives appear to show less of a difference.

Conclusions and Implications from Research Question 5: Question Type and Educational Program for Two-Way Dual Language Immersion Students and Students in a Monolingual English Program

The fifth goal of this study was to investigate whether there is an interaction of question type and educational program, as well as the main effects of question type and group. A comparison of nonvisual questions to all visual questions overall was conducted as well as separate comparisons for nonvisual questions and subsets of certain types of visual including graphs, tables, geometric figures, manipulatives, and patterns. The results of this part of the study indicated a lack of an interaction between program type and educational program for all comparisons except the nonvisual/geometric figures comparison for the Spanish version of the Grade 3 Mathematics TAKS Test and the nonvisual/tables comparison for the English version of the Grade 4 Mathematics TAKS Test. Thus, the educational environment that determined the groups of students for this study does not interact with question type on the Grade 3 and Grade 4 Mathematics TAKS Tests.

The main effect of question type was statistically significant in all comparisons except for the nonvisual/patterns comparison for the Spanish version of the Grade 3 Mathematics TAKS Test and three different comparisons for the Spanish version of the Grade 4 Mathematics TAKS Test: nonvisual/all visual, nonvisual/manipulatives, and nonvisual/patterns. The questions with a visual had a higher mean in all comparisons to nonvisual questions except the nonvisual/patterns comparison on the English version of the Grade 3 Mathematics TAKS Test. The questions with a visual had a higher mean in all comparisons to nonvisual questions except the nonvisual/patterns comparison on the Spanish version of the Grade 3 Mathematics TAKS Test. The questions with a visual had a higher mean in all comparisons to nonvisual questions except the nonvisual/tables and nonvisual/patterns comparisons. The questions with a visual had a higher mean in only four comparisons: nonvisual/graphs for two-way immersion students, nonvisual/all visual for students in a monolingual English program, nonvisual/graphs for students in a monolingual English program, and nonvisual/patterns for students in a monolingual English program. Thus, visuals are making a difference on all versions of the test, and both groups of students are performing better overall on questions that contain a visual than on questions that do not contain a visual. Therefore, educators should include visuals as part of the instructional design of these educational programs.

Questions that contained a graph and questions that contained a geometric image had the highest means of correct responses for both two-way dual language immersion students and monolingual English students on the Grade 3 English and Grade 3 Spanish Mathematics TAKS Test. Therefore, the visuals of a graph and a geometric image appear to have the largest effect on both groups of students at the third-grade level, and educators should certainly include this visual in the instructional design of the program. Questions that contained a table and questions that contained a pattern had the lowest means of correct responses for both two-way dual language immersion students and monolingual English students on the Grade 3 and Grade 3 Spanish Mathematics TAKS Test. Therefore, educators and researchers must carefully analyze the inclusion of these visuals as part of the instructional design of a program. Perhaps the instructional content in these programs and the assessment of this type of content are not carefully aligned.

Questions that contained graphs had the highest means of correct responses for both two-way dual language immersion students and monolingual English students on the Grade 4 English and Grade 4 Spanish Mathematics TAKS Test. Therefore, the visual of a graph appears to have the largest effect on both groups of students at the fourth-grade level, and educators should certainly include this visual in the instructional design of the program. Questions that contained a table and questions that contained a pattern had the lowest means of correct responses for both two-way dual language immersion students and monolingual English students on the Grade 4 English Test.

Questions that contained a table and questions that contained a geometric image had the lowest means of correct responses for both two-way dual language immersion students and monolingual English students on the Grade 4 Spanish Mathematics TAKS Test. Therefore, educators and researchers must carefully analyze the inclusion of these visuals as part of the instructional design of each type of program. In particular, the inclusion of tables at this grade level needs to be carefully analyzed and considered. Perhaps the instructional content in these programs and the assessment of this type of content are not carefully aligned.

The main effect of group was statistically significant in all comparisons on the English version of the Grade 3 Mathematics TAKS Test and the Spanish version of the Grade 4 Mathematics TAKS Test with two-way dual language immersion students having a higher mean in all comparisons. The main effect of group was not statistically significant in any of the comparisons on the Spanish version of the Grade 3 Mathematics TAKS Test and the English version of the Grade 4 Mathematics TAKS Test. On the Spanish version of the Grade 3 Test, the means for nonvisual questions, all visual questions, visual questions with a geometric figure, and visual questions with a manipulative were higher for two-way dual language immersion students. The means for visual questions with a graph, visual questions with a table, and visual questions with a pattern were higher for students in a monolingual English program. On the English version of the Grade 4 Test, the means for all visuals, visual questions with a table, visual questions with a geometric figure, visual questions with a manipulative, and visual questions with a pattern were higher for two-way dual language immersion students. The means for nonvisual questions and visual questions with a graph were higher for students in a monolingual English program. Therefore, the inclusion of visuals seems to be more helpful for two-way dual language immersion students who take the Grade 3 English Mathematics TAKS Test and Grade 4 Spanish Mathematics TAKS Test. Further research is certainly needed in this area to understand the reasons.

Implications and Recommendations for Theory and Practice

The results of this study indicate that two-way dual language immersion programs are not hindering student performance in mathematics, even though students are learning two different languages and mathematics instruction among programs may vary. The only difference in scaled scores that appeared at a statistically significant level was on the Spanish version of the Grade 4 Mathematics TAKS Test. Overall, the lack of a difference in scaled scores should be viewed as a positive motivation for school districts to include more two-way dual language programs. Administrators and educators have evidence to support the idea that the learning of a second language is not going to hinder the achievement of the student in mathematics.

The instructional environment appears to be offering academic advantages for two-way dual language immersion students over those students in a monolingual English program. Thus, educators need to recognize positive academic effects that result from a two-way dual language immersion program. Students from two-way dual language immersion programs are scoring higher on subsets of nonvisual and visual questions at statistically significant differences when compared to students in a monolingual English program on the English version of the Grade 3 Mathematics TAKS Test and the Spanish version of the Grade 4 Mathematics TAKS Test. With few statistically significant results reported between the two groups of students on the Spanish version of the Grade 3 Mathematics TAKS Test and the English version of the Grade 4 Mathematics TAKS Test, educators can conclude that two-way dual language immersion programs are not producing lower percentages of correct responses in these areas as a result of the instruction in two different languages.

Visuals as part of the instructional environment are making a difference in student performance on the Grade 3 and Grade 4 Mathematics TAKS Tests for two-way dual language immersion students. Thus, educators must recognize and include visuals in the instructional design of courses within a two-way dual language program. In particular, this study indicates that visuals that include a graph are important for the instructional design of a two-way dual language immersion program. Questions with a geometric image and questions with a manipulative also should be included for two-way dual language immersion students during instruction based on the results of this study.

Visuals as part of the instructional environment are also making a difference in student performance on the Grade 3 and Grade 4 Mathematics TAKS Tests for students in a monolingual English program. Thus, educators must also recognize and include visuals in the instructional design of courses within a monolingual English program. In particular, this study indicates that visuals that include a graph are important for the instructional design of a monolingual English program. Questions with a geometric image also need to be included for monolingual English students during instruction based on the results of this study.

Educators and researchers should take interest in the result that, although scaled scores were statistically higher, students who took the Spanish version of the Grade 4 Mathematics TAKS Test had the smallest number of statistically significant differences between nonvisual and visual questions. A main effect of group appeared when evaluating the comparison of nonvisual questions to all visual questions and various subsets of visual questions. Two-way dual language immersion students produced higher means most of the time, and this results in an important finding for educators wanting to implement these types of programs in a school district. This main effect for group occurred more often on the Grade 3 test than on the Grade 4 test. Thus, the two-way dual language immersion instructional program seems positive for all students and certainly for the increasing number of Hispanic students as far as mathematic is concerned. While visuals do not seem to explain the higher difference in scaled scores at the fourth-grade level, the fact that scaled scores are higher for the two-way immersion students is significant for educators to consider when deciding to implement a new dual language program in a district.

Limitations and Recommendations for Future Research

A limitation of this study resulted from the exploratory nature of this study based on the existing enrollment of students in either a two-way dual language immersion program or a monolingual education environment. The researcher had no control over academic ability of the students, instructional design of the programs, teachers in the programs, or any factors leading to or prohibiting academic achievement. Thus, the researcher compensated for these limitations by randomly selecting the same number of students in a monolingual education program for each version of the test to match the number of students in the two-way dual language immersion program for the same version of the test.

Delimitations of this study resulted from the choice to focus on third- and fourth-grade students who took the Spring 2009 Mathematics TAKS Test in the state of Texas.

The study lays a foundation for many areas of future research as a second language effect on mathematics learning is further explored. With a gap in research literature focused on the Mathematics TAKS Test at the third- and fourth-grade levels, future studies might repeat this study for other bilingual educational programs and not just focus on the two-way dual language immersion programs compared to monolingual English educational programs. Future studies might also repeat this study with the same set of data and select different random samples to test the results of this study. Future studies might expand beyond the Mathematics TAKS Test and focus on other regions implementing two-way dual language immersion programs in the United States. Future studies could also focus on an analysis of the ethnicity and socio-economic status of the students participating in the study to see if those factors affect the results.

Previous students did not separate mathematics questions by type. While many positive results were found for the inclusion of visuals in instruction for both types of programs, researchers should try to gain an understanding of why patterns and tables appear to show less difference for two-way dual language immersion students. Researchers should try to gain an understanding about why questions with patterns and manipulatives appear to show less difference for monolingual English students. Future studies might also investigate why the inclusion of visuals seems to be more helpful for two-way dual language immersion students who take the Grade 3 English Mathematics TAKS Test and Grade 4 Spanish Mathematics TAKS Test.

With previous studies and literature that focus on the role of analogical reasoning in mathematics instruction (English, 2004a, 2004b; Goswami, 2004), future studies might investigate the role that analogical reasoning plays in the transfer of the visuals from one domain into another. Future studies might also investigate why statistically significant differences are occurring on percentages of correct responses on nonvisual and various categories of visual questions on the English version of the Grade 3 Mathematics TAKS Test and not the English version of the Grade 4 Mathematics TAKS Test. Future studies might also investigate why statistically significant differences are occurring on percentages of correct responses on nonvisual and various categories of visual questions on the Spanish version of the Grade 4 Mathematics TAKS Test and not the Spanish version of the Grade 3 Mathematics TAKS Test. Overall, more research in the areas of the use of visuals in the mathematics classroom and the effects of the implementation of bilingual educational programs to answer a growing need of large Hispanic and ELL populations certainly needs to be conducted to keep mathematics education on an empowering edge.

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APPENDIX A

Organizing the Data

The researcher first imported the comma-delimited text data files into Excel to organize the data. Third-grade data was imported into a separate Excel file from the fourth-grade data. Upon importing, the researcher had to separate the item analysis data for each grade level from one column into separate columns for each question. Notes included with the files indicated that all records were included in the data, results of some records were masked to comply with FERPA (Family Educational Rights and Privacy Act), and student identifying information was not included in the data to also comply with FERPA. Initially, there were 370,777 records for third grade and 360,116 records for fourth grade. Table 31 displays the breakdown of all third- and fourth-grade data by sex, ethnicity, and economic disadvantage coding before sorting and organizing the data based on specific codes. This table is provided by the researcher so that the reader can have an understanding of the number and percentage breakdown of all students taking the Mathematics TAKS Tests at the Grade 3 and Grade 4 levels. Table 32 displays the breakdown of all third- and fourth-grade data by bilingual indicator code, score code, test language, and test version before sorting and organizing the data based on specific codes. This table has been provided by the researcher to provide the reader with an understanding of the number of percentages of students that are coded specific ways based on participation in a bilingual program, the code for scoring, the language of testing, and the version of the test taken.

Table 31

Sex, Ethnicity, and Economic Disadvantage Classification of Students Completing the Grade 3 and Grade 4 Mathematics TAKS Test in Spring 2009

	Third-Grade Test Takers	Percent of Third-Grade Test Takers	Fourth-Grade Test Takers	Percent of Fourth-Grade Test Takers
Total	370,777		360,116	
Sex:				
Female	181,007	48.8%	175,928	48.9%
Male	189,633	51.1%	183,822	51.0%
Missing Code	137	<0.1%	366	0.1%
Ethnicity:				
Amer. Indian or Alaskan	1279	0.3%	1,281	0.4%
Asian or Pacific Islander	13,564	3.7%	12,939	3.6%
African American	51,176	13.8%	49,817	13.8%
Hispanic	182,359	49.2%	174,222	48.4%
White, not Hispanic Origin	121,997	32.9%	121,473	33.7%
Missing Code	402	0.1%	384	0.1%
Economic disadvantage:				
Free meals	158,948	42.9%	151,449	42.1%
Reduced-price meals	31,225	8.4%	30,461	8.5%
Other economic disadvantage	32,501	8.8%	30,054	8.3%
Not identified economic disadvantage	147,556	39.8%	147,624	41.0%
Missing Code	547	0.1%	528	0.1%

Table 32
Bilingual Indicator Code, Score Code, Test Language, and Test Version of Students Completing the Grade 3 and Grade 4 Mathematics TAKS Test in Spring 2009

	Third-Grade Test Takers	Percent of Third-Grade Test Takers	Fourth-Grade Test Takers	Percent of Fourth-Grade Test Takers
Total	370,777		360,116	
Bilingual Indicator Code:				
Trans biling/early exit	29,347	7.9%	22,031	6.1%
Trans biling/late exit	18,962	5.1%	18,485	5.1%
Dual lang imm/two-way	3,507	0.9%	2,804	0.8%
Dual lang imm/one-way	13,888	3.7%	7,378	2.0%
Not in bilingual program	304,392	82.1%	308,831	85.8%
Missing Code	681	0.2%	587	0.2%
Score code:				
Absent	666	0.2%	845	0.2%
No information available	694	0.2%	2,596	0.7%
TAKS-Alt record	3,230	0.9%	2,941	0.8%
Student is LEP exempt	2,670	0.7%	2,818	0.8%
Other (e.g. ill, cheating)	214	<0.1%	255	<0.1%
Score	363,303	98.0%	350,565	97.3%
Missing Code	0	0%	96	<0.1%
Test language:				
English	342,699	92.4%	342,021	95.0%
Spanish	27,384	7.4%	15,499	4.3%
Missing Code	694	0.2%	2,596	0.7%
Test version:				
TAKS (Accommodated)	8,762	2.4%	10,180	2.8%
TAKS	344,448	92.9%	328,770	91.3%
LAT	2,662	0.7%	2,811	0.8%
TAKS-M	10,981	3.0%	12,818	3.6%
TAKS-Alt	3,230	0.9%	2,941	0.8%
Missing Code	694	0.2%	2,596	0.7%

Table 33 displays the breakdown for the English version of the test for third-grade and fourth-grade data by various categories before sorting and organizing the data based on specific codes. Table 34 displays the breakdown for the Spanish version of the test for third- and fourth-grade data by various categories before sorting and organizing the data based on specific codes. These tables are provided by the researcher so that original subgroup percentages can be compared to the subgroup percentages of students in each sample after the random sampling has been completed for the English and the Spanish versions of each test.

Table 33

Sex, Ethnicity, and Economic Disadvantage of Students Completing the English Version of the Grade 3 and Grade 4 Mathematics TAKS Test in Spring 2009

	Third-Grade Test Takers	Percent of Third-Grade Test Takers	Fourth-Grade Test Takers	Percent of Fourth-Grade Test Takers
Total	342,699		342,021	
Sex:				
Female	167,107	48.8%	167,083	48.9%
Male	175,473	51.2%	174,614	51.1%
Missing Code	119	<0.1%	324	0.1%
Ethnicity:				
Amer. Indian or Alaskan	1261	0.4%	1,253	0.4%
Asian or Pacific Islander	13,532	3.9%	12,829	3.8%
African American	50,974	14.9%	49,304	14.4%
Hispanic	154,780	45.2%	157,647	46.1%
White, not Hispanic Origin	121,803	35.5%	120,645	35.3%
Missing Code	349	0.1%	343	0.1%
Economic disadvantage:				
Free meals	139,820	40.8%	139,460	40.8%
Reduced-price meals	29,232	8.5%	29,256	8.6%
Other econ. disadvantage	27,449	8.0%	27,020	7.9%
Not identified economic disadvantage	145,722	42.5%	145,829	42.6%
Missing Code	476	0.1%	456	0.1%

Table 34

Sex, Ethnicity, and Economic Disadvantage of Students Completing the Spanish Version of the Grade 3 and Grade 4 Mathematics TAKS Test in Spring 2009

	Third-Grade Test Takers	Percent of Third-Grade Test Takers	Fourth-Grade Test Takers	Percent of Fourth-Grade Test Takers
Total	27,384		15,499	
Sex:				
Female	13,604	49.7%	7,624	49.2%
Male	13,769	50.3%	7,848	50.6%
Missing Code	11	<0.1%	27	0.2%
Ethnicity:				
American Indian or Alaskan	13	<0.1%	9	0.1%
Asian or Pacific Islander	10	<0.1%	9	0.1%
African American	45	0.2%	29	0.2%
Hispanic	27,211	99.4%	15,387	99.3%
White, not Hispanic Origin	83	0.3%	46	0.3%
Missing Code	22	0.1%	19	0.1%
Economic disadvantage:				
Free meals	18,714	68.3%	10,587	68.3%
Reduced-price meals	1,961	7.2%	1,057	6.8%
Other economic disadvantage	4,990	18.2%	2,782	18.0%
Not identified economic disadvantage	1,685	6.2%	1,033	6.7%
Missing Code	34	0.1%	40	0.3%

Table 35 summarizes the organization and deletion of data records for the Grade 3 and Grade 4 Mathematics TAKS Test. This table has been included so that the reader can have a clear understanding of how data values were sorted and deleted to arrive at the target population of students for sampling. Once records were removed based on a category, they were not included in the count for the next category for removal, even if that condition was met. The researcher first removed data records that lacked item analysis data for the student or in which the student left all of the answers blank. A total of 16,066 records were removed from the third-grade set, and 18,861 were removed from the fourth-grade set. Because this study was only interested in students who were coded as 4 (dual language immersion/two-way) or 0 (student is not participating in a state-approved full bilingual program) for the bilingual indicator code, the researcher next removed data records that were either not coded or were coded as 2 (transitional bilingual/early exit), 3 (transitional bilingual/late exit), or 5(dual language immersion/one-way). A total of 59,060 records were removed from the third-grade set, and 44,943 were removed from the fourth-grade set. Out of the third-grade records that were removed, 27,709 were coded as 2, 17,943 were coded as 3, 13,065 were coded as 5, and 343 were not coded. Out of the fourth-grade records that were removed, 20,465 were coded as 2, 17,317 were coded as 3, 6,867 were coded as 5, and 294 were not coded.

The researcher next focused on the score coding. Only those records with a code of S were not removed from the data sets. Records with codings of A (absent), L (LEP exempt student), * (no information available), and O (other such as illness, cheating) were removed. A total of 152 records were removed from the third-grade set, and 136 were removed from the fourth-grade set. The researcher was uncertain how 2 of the records could be coded as A for the third-grade set and have item analysis data for that student, but these were removed since they were coded as A. Five records were coded as L, and 145 records were coded as O in the third-grade set.

Table 35
Organization Based on Item Analysis Data, Bilingual Coding, Score Coding, and Mathematics Test Version of Students Completing the Grade 3 and Grade 4 Spring 2009 Mathematics TAKS Test

	Total number of third-grade test takers	Breakdown of third-grade test takers deleted based on code	Total number of fourth-grade test takers	Breakdown of fourth-grade test takers deleted based on code
Beginning Total	370,777		360,116	
Lacking item analysis data	16,066		18,861	
Bilingual Coding not 0 or 4	59,060	Code 2: 27,709 Code 3: 17,943 Code 5: 13,065 No Code: 343	44,943	Code 2: 20,465 Code 3: 17,317 Code 5: 6,867 No Code: 294
Score coding not an S	152	Code A: 2 Code L: 5 Code O: 145	136	Code *: 22 Code A: 12 Code L: 6 Code O: 96
Mathematics test version not a K	16,364	Code A: 7,185 Code M: 9,179	18,828	Code A: 8,424 Code M: 10,404
Remaining Total	279,135		277,348	

Note. Once records were removed based on a category, they were not included in the count for the next category for removal, even if that condition was met. The table is arranged in order from top to bottom based on categories used to remove records. Bilingual code of 0 = student is not participating in a state-approved full bilingual program, 2 = transitional bilingual/early exit, 3 = transitional bilingual/late exit, 4 = dual language immersion/two-way, 5 = dual language immersion/one-way; Score code of * = no information available, A = absent, L = LEP exempt student, O = other such as illness, cheating; Mathematics test version code of A = TAKS accommodated form, M = TAKS-M which is a modified form

The researcher then focused on the mathematics test version. Only those records coded with K (indicating the regular TAKS test) were retained for analysis from the data sets. Students that were removed for taking modified and accommodated versions of the test do not bias the study. Records with codings of A (TAKS accommodated form) and M (TAKS-M which is a modified form) were removed from the data sets. A total of

16,364 records were removed from the third-grade set, and 18,828 were removed from the fourth-grade set.

Table 36 summarizes the remaining records based on test version and bilingual coding after all other records had been removed from the data sets. This table has been provided by the researcher so that the reader understands how many records are left as part of each targeted population of students. Out of the 279,135 records that remained at this time in the third-grade data set, 275,615 took the English version of the test and were coded as 0 for not participating in a bilingual program. There were 1,581 who took the English version of the test and were coded as 4 for participating in a two-way dual language immersion program. For students who took the Spanish version of the third-grade test, 263 were coded as 0, and 1,676 were coded as 4. Out of the 277,348 records that remained at this time in the fourth-grade data set, 274,587 took the English version of the test and were coded as 0 for not participating in a bilingual program. There were 1,403 who took the English version of the test and were coded as 4 for participating in a two-way dual language immersion program. For students who took the Spanish version of the fourth-grade test, 205 were coded as 0, and 1,153 were coded as 4.

Table 36

Grade 3 and Grade 4 Mathematics TAKS Data Breakdown of English and Spanish Test Takers with a Bilingual Code of 0 and 4 from Spring 2009

	Number of third-grade test takers	Number of fourth-grade test takers
	279,135	277,348
English test	277,196	275,990
Coded as 0	275,615	274,587
Coded as 4	1,581	1,403
Spanish test	1,939	1,358
Coded as 0	263	205
Coded as 4	1,676	1,153

Note. Bilingual code of 0 = student is not participating in a state-approved full bilingual program, 4 = dual language immersion/two-way

Sampling the Data

Because the English and Spanish versions of each Mathematics TAKS Test were different, the researcher needed equal sample sizes of students coded as 4 and 0 for each grade level and version of the test. Since 1,581 third-grade students were coded as 4 and took the English version of the test, a random sample of 1,581 from the 275,615 students coded as 0 who took the English version of the test was chosen. Because 275,615 divided by 1,581 equals 174.3, the researcher used the modular arithmetic function in Excel to identify every 174th student in the list of 275,615 until a sample size total of 1,581 was reached. Since 263 third-grade students were coded as 0 and took the Spanish version of the test, a random sample of 263 from the 1,676 students coded as 4 who took the Spanish version of the test was chosen. Because 1,676 divided by 263 equals 6.4, the researcher used the modular arithmetic function in Excel to identify every 6th student in the list of 1,676 until a sample size total of 263 was reached. Since 1,403 fourth-grade students were coded as 4 and took the English version of the test, a random sample of 1,403 from the 274,587 students coded as 0 who took the English version of the test was chosen. Because 274,587 divided by 1,403 equals 195.7, the researcher used the modular arithmetic function in Excel to identify every 195th student in the list of 274,602 until a sample size total of 1,403 was reached. Since 205 fourth-grade students were coded as 0 and took the Spanish version of the test, a random sample of 205 from the 1,153 students coded as 4 who took the Spanish version of the test. Because 1,153 divided by 205 equals 5.6, the researchers used the modular arithmetic function in Excel to identify every 5th student in the list of 1,153 until a sample size total of 205 was reached.

APPENDIX B

Table 37 shows the identification of the two subsets of questions grouped by categories from the English version of the 2009 Grade 3 Mathematics TAKS Test (TEA, 2009d), and Table 38 shows the identification of the two subsets of questions grouped by categories from the Spanish version of the 2009 Grade 3 Mathematics TAKS TEST (TEA, 2009e).

Table 37

Identification of Questions With and Without a Visual Prompt on the English Version of the Spring 2009 Grade 3 Mathematics TAKS Test

Questions without a visual: (10 questions)	3, 5, 8, 10, 12, 21, 24, 28, 34, 37
Questions with a visual: (30 questions)	
Graphs	4, 6, 23, 31, 36, 40
Tables	15, 16, 17, 22, 35, 36
Geometric Figures	2, 11, 13, 19, 29, 33, 38
Images Used as Manipulatives	1, 7, 9, 11, 14, 20, 30, 31, 32, 39
Patterns	18, 25, 26, 27

Note. Questions 11, 31, and 36 contained visuals that were included as part of two different categories.

Table 38

Identification of Questions With and Without a Visual Prompt on the Spanish Version of the Spring 2009 Grade 3 Mathematics TAKS Test

Questions without a visual: (13 questions)	4, 11, 13, 17, 19, 20, 22, 25, 26, 29, 32, 33, 38
Questions with a visual: (27 questions)	
Graphs	3, 7, 15, 27, 36, 37
Tables	3, 14, 18, 24, 36
Geometric Figures	1, 6, 9, 34, 39, 40
Images Used as Manipulatives	2, 5, 7, 9, 10, 12, 16, 21, 28, 30, 31, 35
Patterns	8, 23, 24

Note. Questions 3, 7, 9, 24, and 36 contained visuals that were included as part of two different categories.

Table 39 shows the identification of the two subsets of questions grouped by categories from the English version of the 2009 Grade 4 Mathematics TAKS Test (TEA, 2009f), and Table 40 shows the identification of the two subsets of questions grouped by categories from the Spanish version of the 2009 Grade 4 Mathematics TAKS TEST (TEA, 2009g).

Table 39

Identification of Questions With and Without a Visual Prompt on the English Version of the Spring 2009 Grade 4 Mathematics TAKS Test

Questions without a visual: (14 questions)	3, 6, 9, 12, 18, 19, 21, 24, 29, 33, 36, 38, 40, 41
Questions with a visual: (28 questions)	
Graphs	1, 8, 26, 39, 42
Tables	15, 25, 28
Geometric Figures	2, 7, 20, 34
Images Used as Manipulatives	4, 11, 13, 14, 17, 22, 23, 30, 32, 37
Patterns	5, 10, 16, 27, 31, 35

Table 40

Identification of Questions With and Without a Visual Prompt on the Spanish Version of the Spring 2009 Grade 4 Mathematics TAKS Test

Questions without a visual: (15 questions)	3, 7, 8, 10, 11, 14, 18, 19, 22, 26, 29, 35, 36, 37, 40
Questions with a visual: (27 questions)	
Graphs	2, 13, 24, 30, 34, 41
Tables	31, 32, 39, 42
Geometric Figures	4, 5, 6, 16, 25, 33
Images Used as Manipulatives	1, 4, 5, 15, 17, 20, 23, 27, 28, 30
Patterns	9, 12, 21, 38

Note. Questions 4, 5 and 30 contained visuals that were included as part of two different categories.

APPENDIX C

The Mathematics TEKS for Grade 3 and Grade 4 are included in this appendix and were copied from http://ritter.tea.state.tx.us/rules/tac/chapter111/ch111a.html.

§111.15. Mathematics, Grade 3.

(a) Introduction.

(1) Within a well-balanced mathematics curriculum, the primary focal points at Grade 3 are multiplying and dividing whole numbers, connecting fraction symbols to fractional quantities, and standardizing language and procedures in geometry and measurement.

(2) Throughout mathematics in Grades 3-5, students build a foundation of basic understandings in number, operation, and quantitative reasoning; patterns, relationships, and algebraic thinking; geometry and spatial reasoning; measurement; and probability and statistics. Students use algorithms for addition, subtraction, multiplication, and division as generalizations connected to concrete experiences; and they concretely develop basic concepts of fractions and decimals. Students use appropriate language and organizational structures such as tables and charts to represent and communicate relationships, make predictions, and solve problems. Students select and use formal language to describe their reasoning as they identify, compare, and classify two- or three-dimensional geometric figures; and they use numbers, standard units, and measurement tools to describe and compare objects, make estimates, and solve application problems. Students organize data, choose an appropriate method to display the data, and interpret the data to make decisions and predictions and solve problems.

(3) Throughout mathematics in Grades 3-5, students develop numerical fluency with conceptual understanding and computational accuracy. Students in Grades 3-5 use knowledge of the base-ten place value system to compose and decompose numbers in order to solve problems requiring precision, estimation, and reasonableness. By the end of Grade 5, students know basic addition, subtraction, multiplication, and division facts and are using them to work flexibly, efficiently, and accurately with numbers during addition, subtraction, multiplication, and division computation.

(4) Problem solving, language and communication, connections within and outside mathematics, and formal and informal reasoning underlie all content areas in mathematics. Throughout mathematics in Grades 3-5, students use these

processes together with technology and other mathematical tools such as manipulative materials to develop conceptual understanding and solve meaningful problems as they do mathematics.

(b) Knowledge and skills.

(1) Number, operation, and quantitative reasoning. The student uses place value to communicate about increasingly large whole numbers in verbal and written form, including money. The student is expected to:

(A) use place value to read, write (in symbols and words), and describe the value of whole numbers through 999,999;

(B) use place value to compare and order whole numbers through 9,999; and

(C) determine the value of a collection of coins and bills.

(2) Number, operation, and quantitative reasoning. The student uses fraction names and symbols (with denominators of 12 or less) to describe fractional parts of whole objects or sets of objects. The student is expected to:

(A) construct concrete models of fractions;

(B) compare fractional parts of whole objects or sets of objects in a problem situation using concrete models;

(C) use fraction names and symbols to describe fractional parts of whole objects or sets of objects; and

(D) construct concrete models of equivalent fractions for fractional parts of whole objects.

(3) Number, operation, and quantitative reasoning. The student adds and subtracts to solve meaningful problems involving whole numbers. The student is expected to:

(A) model addition and subtraction using pictures, words, and numbers; and

(B) select addition or subtraction and use the operation to solve problems involving whole numbers through 999.

(4) Number, operation, and quantitative reasoning. The student recognizes and solves problems in multiplication and division situations. The student is expected to:

(A) learn and apply multiplication facts through 12 by 12 using concrete models and objects;

(B) solve and record multiplication problems (up to two digits times one digit); and

(C) use models to solve division problems and use number sentences to record the solutions.

(5) Number, operation, and quantitative reasoning. The student estimates to determine reasonable results. The student is expected to:

(A) round whole numbers to the nearest ten or hundred to approximate reasonable results in problem situations; and

(B) use strategies including rounding and compatible numbers to estimate solutions to addition and subtraction problems.

(6) Patterns, relationships, and algebraic thinking. The student uses patterns to solve problems. The student is expected to:

(A) identify and extend whole-number and geometric patterns to make predictions and solve problems;

(B) identify patterns in multiplication facts using concrete objects, pictorial models, or technology; and

(C) identify patterns in related multiplication and division sentences (fact families) such as $2 \times 3 = 6$, $3 \times 2 = 6$, $6 \div 2 = 3$, $6 \div 3 = 2$.

(7) Patterns, relationships, and algebraic thinking. The student uses lists, tables, and charts to express patterns and relationships. The student is expected to:

(A) generate a table of paired numbers based on a real-life situation such as insects and legs; and

(B) identify and describe patterns in a table of related number pairs based on a meaningful problem and extend the table.

(8) Geometry and spatial reasoning. The student uses formal geometric vocabulary. The student is expected to identify, classify, and describe two- and three-dimensional geometric figures by their attributes. The student compares two- dimensional figures, three-dimensional figures, or both by their attributes using formal geometry vocabulary.

(9) Geometry and spatial reasoning. The student recognizes congruence and symmetry. The student is expected to:

> (A) identify congruent two-dimensional figures;
>
> (B) create two-dimensional figures with lines of symmetry using concrete models and technology; and
>
> (C) identify lines of symmetry in two-dimensional geometric figures.

(10) Geometry and spatial reasoning. The student recognizes that a line can be used to represent numbers and fractions and their properties and relationships. The student is expected to locate and name points on a number line using whole numbers and fractions, including halves and fourths.

(11) Measurement. The student directly compares the attributes of length, area, weight/mass, and capacity, and uses comparative language to solve problems and answer questions. The student selects and uses standard units to describe length, area, capacity/volume, and weight/mass. The student is expected to:

> (A) use linear measurement tools to estimate and measure lengths using standard units;
>
> (B) use standard units to find the perimeter of a shape;
>
> (C) use concrete and pictorial models of square units to determine the area of two-dimensional surfaces;
>
> (D) identify concrete models that approximate standard units of weight/mass and use them to measure weight/mass;
>
> (E) identify concrete models that approximate standard units for capacity and use them to measure capacity; and
>
> (F) use concrete models that approximate cubic units to determine the volume of a given container or other three-dimensional geometric figure.

(12) Measurement. The student reads and writes time and measures temperature in degrees Fahrenheit to solve problems. The student is expected to:

(A) use a thermometer to measure temperature; and

(B) tell and write time shown on analog and digital clocks.

(13) Probability and statistics. The student solves problems by collecting, organizing, displaying, and interpreting sets of data. The student is expected to:

(A) collect, organize, record, and display data in pictographs and bar graphs where each picture or cell might represent more than one piece of data;

(B) interpret information from pictographs and bar graphs; and

(C) use data to describe events as more likely than, less likely than, or equally likely as.

(14) Underlying processes and mathematical tools. The student applies Grade 3 mathematics to solve problems connected to everyday experiences and activities in and outside of school. The student is expected to:

(A) identify the mathematics in everyday situations;

(B) solve problems that incorporate understanding the problem, making a plan, carrying out the plan, and evaluating the solution for reasonableness;

(C) select or develop an appropriate problem-solving plan or strategy, including drawing a picture, looking for a pattern, systematic guessing and checking, acting it out, making a table, working a simpler problem, or working backwards to solve a problem; and

(D) use tools such as real objects, manipulatives, and technology to solve problems.

(15) Underlying processes and mathematical tools. The student communicates about Grade 3 mathematics using informal language. The student is expected to:

(A) explain and record observations using objects, words, pictures, numbers, and technology; and

(B) relate informal language to mathematical language and symbols.

(16) Underlying processes and mathematical tools. The student uses logical reasoning. The student is expected to:

(A) make generalizations from patterns or sets of examples and nonexamples; and

(B) justify why an answer is reasonable and explain the solution process.

Source: The provisions of this §111.15 adopted to be effective September 1, 1998, 22 TexReg 7623; amended to be effective August 1, 2006, 30 TexReg 7471.

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§111.16. Mathematics, Grade 4.

(a) Introduction.

(1) Within a well-balanced mathematics curriculum, the primary focal points at Grade 4 are comparing and ordering fractions and decimals, applying multiplication and division, and developing ideas related to congruence and symmetry.

(2) Throughout mathematics in Grades 3-5, students build a foundation of basic understandings in number, operation, and quantitative reasoning; patterns, relationships, and algebraic thinking; geometry and spatial reasoning; measurement; and probability and statistics. Students use algorithms for addition, subtraction, multiplication, and division as generalizations connected to concrete experiences; and they concretely develop basic concepts of fractions and decimals. Students use appropriate language and organizational structures such as tables and charts to represent and communicate relationships, make predictions, and solve problems. Students select and use formal language to describe their reasoning as they identify, compare, and classify two- or three-dimensional geometric figures; and they use numbers, standard units, and measurement tools to describe and compare objects, make estimates, and solve application problems. Students organize data, choose an appropriate method to display the data, and interpret the data to make decisions and predictions and solve problems.

(3) Throughout mathematics in Grades 3-5, students develop numerical fluency with conceptual understanding and computational accuracy. Students in Grades 3-5 use knowledge of the base-ten place value system to compose and decompose numbers in order to solve problems requiring precision, estimation, and reasonableness. By the end of Grade 5, students know basic addition, subtraction, multiplication, and division facts and are using them to work

flexibly, efficiently, and accurately with numbers during addition, subtraction, multiplication, and division computation.

(4) Problem solving, language and communication, connections within and outside mathematics, and formal and informal reasoning underlie all content areas in mathematics. Throughout mathematics in Grades 3-5, students use these processes together with technology and other mathematical tools such as manipulative materials to develop conceptual understanding and solve meaningful problems as they do mathematics.

(b) Knowledge and skills.

(1) Number, operation, and quantitative reasoning. The student uses place value to represent whole numbers and decimals. The student is expected to:

(A) use place value to read, write, compare, and order whole numbers through 999,999,999; and

(B) use place value to read, write, compare, and order decimals involving tenths and hundredths, including money, using concrete objects and pictorial models.

(2) Number, operation, and quantitative reasoning. The student describes and compares fractional parts of whole objects or sets of objects. The student is expected to:

(A) use concrete objects and pictorial models to generate equivalent fractions;

(B) model fraction quantities greater than one using concrete objects and pictorial models;

(C) compare and order fractions using concrete objects and pictorial models; and

(D) relate decimals to fractions that name tenths and hundredths using concrete objects and pictorial models.

(3) Number, operation, and quantitative reasoning. The student adds and subtracts to solve meaningful problems involving whole numbers and decimals. The student is expected to:

(A) use addition and subtraction to solve problems involving whole numbers; and

(B) add and subtract decimals to the hundredths place using concrete objects and pictorial models.

(4) Number, operation, and quantitative reasoning. The student multiplies and divides to solve meaningful problems involving whole numbers. The student is expected to:

(A) model factors and products using arrays and area models;

(B) represent multiplication and division situations in picture, word, and number form;

(C) recall and apply multiplication facts through 12 x 12;

(D) use multiplication to solve problems (no more than two digits times two digits without technology); and

(E) use division to solve problems (no more than one-digit divisors and three-digit dividends without technology).

(5) Number, operation, and quantitative reasoning. The student estimates to determine reasonable results. The student is expected to:

(A) round whole numbers to the nearest ten, hundred, or thousand to approximate reasonable results in problem situations; and

(B) use strategies including rounding and compatible numbers to estimate solutions to multiplication and division problems.

(6) Patterns, relationships, and algebraic thinking. The student uses patterns in multiplication and division. The student is expected to:

(A) use patterns and relationships to develop strategies to remember basic multiplication and division facts (such as the patterns in related multiplication and division number sentences (fact families) such as $9 \times 9 = 81$ and $81 \div 9 = 9$); and

(B) use patterns to multiply by 10 and 100.

(7) Patterns, relationships, and algebraic thinking. The student uses organizational structures to analyze and describe patterns and relationships. The student is expected to describe the relationship between two sets of related data such as ordered pairs in a table.

(8) Geometry and spatial reasoning. The student identifies and describes attributes of geometric figures using formal geometric language. The student is expected to:

(A) identify and describe right, acute, and obtuse angles;

(B) identify and describe parallel and intersecting (including perpendicular) lines using concrete objects and pictorial models; and

(C) use essential attributes to define two- and three-dimensional geometric figures.

(9) Geometry and spatial reasoning. The student connects transformations to congruence and symmetry. The student is expected to:

(A) demonstrate translations, reflections, and rotations using concrete models;

(B) use translations, reflections, and rotations to verify that two shapes are congruent; and

(C) use reflections to verify that a shape has symmetry.

(10) Geometry and spatial reasoning. The student recognizes the connection between numbers and their properties and points on a line. The student is expected to locate and name points on a number line using whole numbers, fractions such as halves and fourths, and decimals such as tenths.

(11) Measurement. The student applies measurement concepts. The student is expected to estimate and measure to solve problems involving length (including perimeter) and area. The student uses measurement tools to measure capacity/volume and weight/mass. The student is expected to:

(A) estimate and use measurement tools to determine length (including perimeter), area, capacity and weight/mass using standard units SI (metric) and customary;

(B) perform simple conversions between different units of length, between different units of capacity, and between different units of weight within the customary measurement system;

(C) use concrete models of standard cubic units to measure volume;

(D) estimate volume in cubic units; and

(E) explain the difference between weight and mass.

(12) Measurement. The student applies measurement concepts. The student measures time and temperature (in degrees Fahrenheit and Celsius). The student is expected to:

(A) use a thermometer to measure temperature and changes in temperature; and

(B) use tools such as a clock with gears or a stopwatch to solve problems involving elapsed time.

(13) Probability and statistics. The student solves problems by collecting, organizing, displaying, and interpreting sets of data. The student is expected to:

(A) use concrete objects or pictures to make generalizations about determining all possible combinations of a given set of data or of objects in a problem situation; and

(B) interpret bar graphs.

(14) Underlying processes and mathematical tools. The student applies Grade 4 mathematics to solve problems connected to everyday experiences and activities in and outside of school. The student is expected to:

(A) identify the mathematics in everyday situations;

(B) solve problems that incorporate understanding the problem, making a plan, carrying out the plan, and evaluating the solution for reasonableness;

(C) select or develop an appropriate problem-solving plan or strategy, including drawing a picture, looking for a pattern, systematic guessing and checking, acting it out, making a table, working a simpler problem, or working backwards to solve a problem; and

(D) use tools such as real objects, manipulatives, and technology to solve problems.

(15) Underlying processes and mathematical tools. The student communicates about Grade 4 mathematics using informal language. The student is expected to:

(A) explain and record observations using objects, words, pictures, numbers, and technology; and

(B) relate informal language to mathematical language and symbols.

(16) Underlying processes and mathematical tools. The student uses logical reasoning. The student is expected to:

(A) make generalizations from patterns or sets of examples and nonexamples; and

(B) justify why an answer is reasonable and explain the solution process.

Source: The provisions of this §111.16 adopted to be effective September 1, 1998, 22 TexReg 7623; amended to be effective August 1, 2006, 30 TexReg 7471.

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