

**The Effects of English Language Proficiency and Scientific Reasoning Skills on the Acquisition of Science Content Knowledge by Hispanic English Language Learners and Native English Language Speaking Students**

by

Hector N. Torres  
University of Massachusetts

and

Dana L. Zeidler  
University of South Florida

Introduction and Purpose of the Study

Scientific literacy for all students has been a major educational goal in the United States of America (American Association for the Advancement of Science, 1989, 1990; National Research Council, 1995). According to the National Research Council (1995), “an understanding of science makes it possible to discuss scientific issues that affect society, to use scientific knowledge and processes in making personal decisions, and to share in the excitement of scientific discovery and comprehension” (p. ix). Often, this understanding of science has proven to be very elusive for Hispanic English language learners in the United States. It has been stated by the American Association for the Advancement of Science (1990), that to neglect the science education of students is to deprive them of a basic education, handicap them for life, and deprive the nation of talented workers and informed citizens. The neglect of science education for Hispanic English language learners today appears to be most prevalent in the classrooms of America (American Association for the Advancement of Science, 1989, 1990; National Research Council, 1995).

In most classrooms in the United States, the English language is used as the medium of instruction for science. Therefore, one of the objectives of this research study was to examine the effects of English language proficiency on the acquisition of science content knowledge by Hispanic English language learners. The theoretical foundation to investigate this factor was Cummins' (1981, 1986, 1991) work on cognitive academic language proficiency, which relates both cognitive and linguistic processes to the academic success of students, more specifically non-native English language learners. According to Cummins (1980), there are two levels of language proficiency: the basic interpersonal communicative skills (BICS) and the cognitive-academic language proficiency (CALP). The basic interpersonal communicative skills (BICS) concept represents the language of natural, informal conversation. Basic interpersonal communicative skills (BICS) are used by students when talking about everyday things in concrete situations, that is; situations in which the context provides cues that make understanding not totally dependent on verbal interaction alone (Cummins, 1980, 1992; Skutnabb-Kangus, 1981). Cummins (1980) refers to this everyday conversational ability as context embedded or contextualized. It has been found by Cummins (1980, 1992) and more recently by Rosenthal (1996) that in context embedded or contextualized communication, the conversation deals with familiar events or matters that require that the speakers react and respond to each other. However, according to Cummins (1980, 1981), Krashen and Biber (1987), Rosenthal (1996) and Spurlin (1995), CALP is the type of language proficiency needed to read textbooks, to participate in dialogue and debate, and to provide written responses to

tests. Students who have not yet developed their cognitive-academic language proficiency (CALP) could be, according to these researchers, at a disadvantage in learning science or other academic subject matter.

A second objective of this study was to investigate the effects of scientific reasoning skills on the acquisition of science content knowledge by Hispanic English language learners and native English language speaking students participating in Grade 10 science classes. To examine this factor, the researchers drew on the work of Lawson, McElrath, Burton, James, Doyle, Woodward, Kellerman, and Snyder (1991) on levels of scientific reasoning skills, which indicates that formal reasoning, is a prerequisite for most high school science courses. Lawson et al. (1991) hypothesized that the use of a general pattern of formal reasoning is necessary for the acquisition of new science concepts. During the formal operational stage, students acquire scientific thinking with its hypothetico-deductive reasoning and logical reasoning with its interpropositional reasoning (Flavell, Miller & Miller, 1993). It is commonly understood that at the level of formal operations, thinking reaches its highest degree of equilibrium (Anderson, 1980; Inhelder & Piaget, 1958; Piaget, 1964). This means, according to Piaget, that the various operations are tightly interrelated and that they apply to the widest possible field of application, that is, the realm of hypothetical possibilities. Lawson et al. (1991) tested the hypothesis that the acquisition of domain-specific conceptual knowledge (declarative knowledge) requires use of general procedural knowledge. Lawson et al. hypothesized that the use of a general pattern of hypothetico-deductive reasoning is necessary for the acquisition of novel domain-specific concepts. The hypothesis was tested using high school native English language speaking students taking biology, chemistry and physics courses. This work enabled Lawson et al. to categorize

students based on their responses on various reasoning tasks, as intuitive thinkers (i.e., having empirico-deductive reasoning), transitional thinkers (i.e., scoring somewhere between intuitive and reflective thinking) or reflective thinkers (i.e., having hypothetico-deductive reasoning skills). This study followed Lawson's et al. rationale and used their terminology; intuitive, transitional, and reflective thinkers, rather than Piaget's terms of concrete and formal operational thinking to classify the students' scientific reasoning skills on standardized science tests.

Notwithstanding the work of Cummins and Lawson et al., the researchers found relatively few studies (e.g., August & Hakuta, 1997; Chi, de Leeuw, Chiu, & La Vancher, 1994; Cocking & Chipman, 1988; Cocking & Mestre, 1988) examining the effects of both English language proficiency and scientific reasoning skills on the learning of science content knowledge of Hispanic English language learners. Both past research and theory (Cummins, 1980, 1981; Lawson, 1978, 1981; Lawson et al., 1991) suggested that English language proficiency and levels of scientific reasoning skills could affect or are prerequisite for the acquisition of science content knowledge. Accordingly, the researchers choose to further investigate and delineate this presupposition. The following research questions were investigated:

- 1) What are the effects of English language proficiency and levels of scientific reasoning skills on the acquisition of science content knowledge of Hispanic English language learners participating in Grade 10 science classes?
- 2) Do English language proficiency and scientific reasoning skills interact to influence the acquisition of science content knowledge by Hispanic English language learners and native English language speaking students participating in Grade 10 science

classes?

## Rationale and Theoretical Framework of the Study

### Hispanic English language learners and High School Science

This study examined the effects of two variables, English language proficiency and levels of scientific reasoning skills of Hispanic English language learners and native English language speaking students, on their acquisition of science content knowledge. Examining these variables using students taking Grade 10 earth science, biology and chemistry classes was appropriate and relevant, for at this age, students display a variety of reasoning abilities but are often called upon to learn concepts which require the use of formal reasoning skills (Anderson, 1991; Flavell, Miller & Miller, 1993; Karplus, Adi, & Lawson, 1980; Lawson, 1990; Piaget, 1970a, 1970b; Zeidler, 1985). According to Zeidler (1985), “There is evidence which suggests that individuals have the ability to use their formal reasoning skills somewhat more consistently at the tenth grade level than earlier grades in which students are apt to be transitional” (p. 462). Piaget (1970a, 1970b, 1985) documented that the process of scientific reasoning becomes formal operational during adolescence.

Prior to the 1960’s the United States of America system of education focused mostly on the needs of native English language speaking students. Since then, a large number of Hispanic English language learners have entered the United States of America school classrooms. At one point, these Hispanic English language learners were expected to “sink or swim” in a school system that paid little attention to their linguistic or cultural background (National Research Council, 1997; Rosenthal, 1996). Today, there are a variety of educational approaches (English as a Second Language, Content-based ESL, Sheltered instruction,

Structured immersion, Transitional Bilingual Education, Maintenance bilingual education, Two-way bilingual programs) aimed at meeting the linguistic and cultural needs of Hispanic English language learners. These educational approaches have been put in place to help these students develop their proficiency in English and learn content knowledge, skills and attitudes in compliance with local and/or state curriculum frameworks. A number of studies (August & Hakuta, 1997; Fitzgerald, 1995) have been conducted in the areas of language acquisition, cognitive development and instructional approaches for Hispanic English language learners. These studies claim that in spite of the effectiveness or lack of effectiveness of these approaches, Hispanic English language learners continue to show poor academic achievement in content areas such as science and mathematics.

According to the National Research Council (1997), research studies have not empirically addressed the need for Hispanic English language learners to develop a relatively high degree of English language proficiency in order to understand and learn science concepts. Traditionally the approaches used in educating Hispanic English language learners have been considered as almost entirely language-based through transitional bilingual education programs. The main objective of these transitional bilingual education programs is to prepare English language learners to succeed academically in standard curriculum classes taught in English. In fact, as reported by the National Research Council (1997), much of the current educational research on English language learners has focused on language acquisition issues. While this has been the trend, the National Research Council (1997), has acknowledged and recommended

that action be taken to conduct research in the area of learning and understanding content knowledge in a second language.

English language proficiency is presumed to be one important contributor to the unexplained variance of the differences in academic achievement between Hispanic English language learners and native English language speaking students (Canale, 1981; Cummins, 1981, 1991). Data from other studies (Anderson & Anderson, 1970; August & Hakuta, 1997; Baral, 1979; Brown, 1973; Canale, 1981; Carrasquillo & Rodriguez, 1996; Connor & Kaplan, 1987; Cummins, 1981, 1991; Krashen, 1976, 1986; Oller, 1980) have shown a relationship between English reading and writing and academic achievement. However, very few studies, with the exception of those conducted by Aiken (1971a, 1971b), Baral (1979), Bender and Ruiz (1974), Cocking and Chipman (1988), Cottrell (1968), Goodrum (1978), have attempted to investigate the relationship or effects of English language proficiency on the acquisition of science content knowledge. Rather, what these studies have examined is the relationship between achievement in domain specific concepts such as mathematics and verbal ability in the general population.

## English language proficiency

Language is an integral part of culture, and the words that we have and how we use them reflect our values and belief system (Rosenthal, 1996). The native language we speak and use is determined by the culture in which we are raised and schooled (Connor & Kaplan, 1987; Damen, 1987; Richard-Amato & Snow, 1992; Rosenthal, 1996). Various educational researchers (Krashen, 1976, 1981, 1982; Krashen, Long & Scarcella, 1979) suggest that there is a distinction between unconscious language acquisition and conscious language learning. For Krashen et al. the native language proficiency, which everyone develops, is an example of unconscious language acquisition.

Krashen et al. (1979) furthermore, claimed that studying a second language taught by teachers, using textbooks, taking formal classes and learning the rules, vocabulary, grammar, and idioms of the second language, is an example of conscious language learning. Educational and linguistic theorists (Cummins, 1980; Krashen, 1976, 1981, 1982; & Krashen et al., 1979) suggest that in the case of Hispanic English language learners, these students may become quite proficient in the grammar, vocabulary and sentence structure of the English language, but may lack the necessary cognitive academic language proficiency to learn the subject matter that is presented to them in science classrooms. In other words, these students may be proficient in their English communication skills but may not have the cognitive academic language proficiency (CALP) required for learning science or other academic subject matter.

The cognitive-academic language proficiency (CALP) concept, is related to literacy



skills in the first or second language and according to Cummins, requires both higher levels of language and cognitive processes in order to develop the language proficiency needed for success and achievement in school. Cummins (1982), Chamot and O'Malley (1986) and Shuy (1978, 1981), have conceptualized the relationship of language proficiency and academic achievement by using an iceberg representation (See Figure 1 below). In this representation, basic interpersonal communications skills (BICS), or skills, which depend on the surface features of language and lower levels of cognitive processes, are represented above the waterline while the cognitive-academic language proficiency (CALP) or skills related to the meaning of language and higher level of cognitive processes are represented below the waterline.

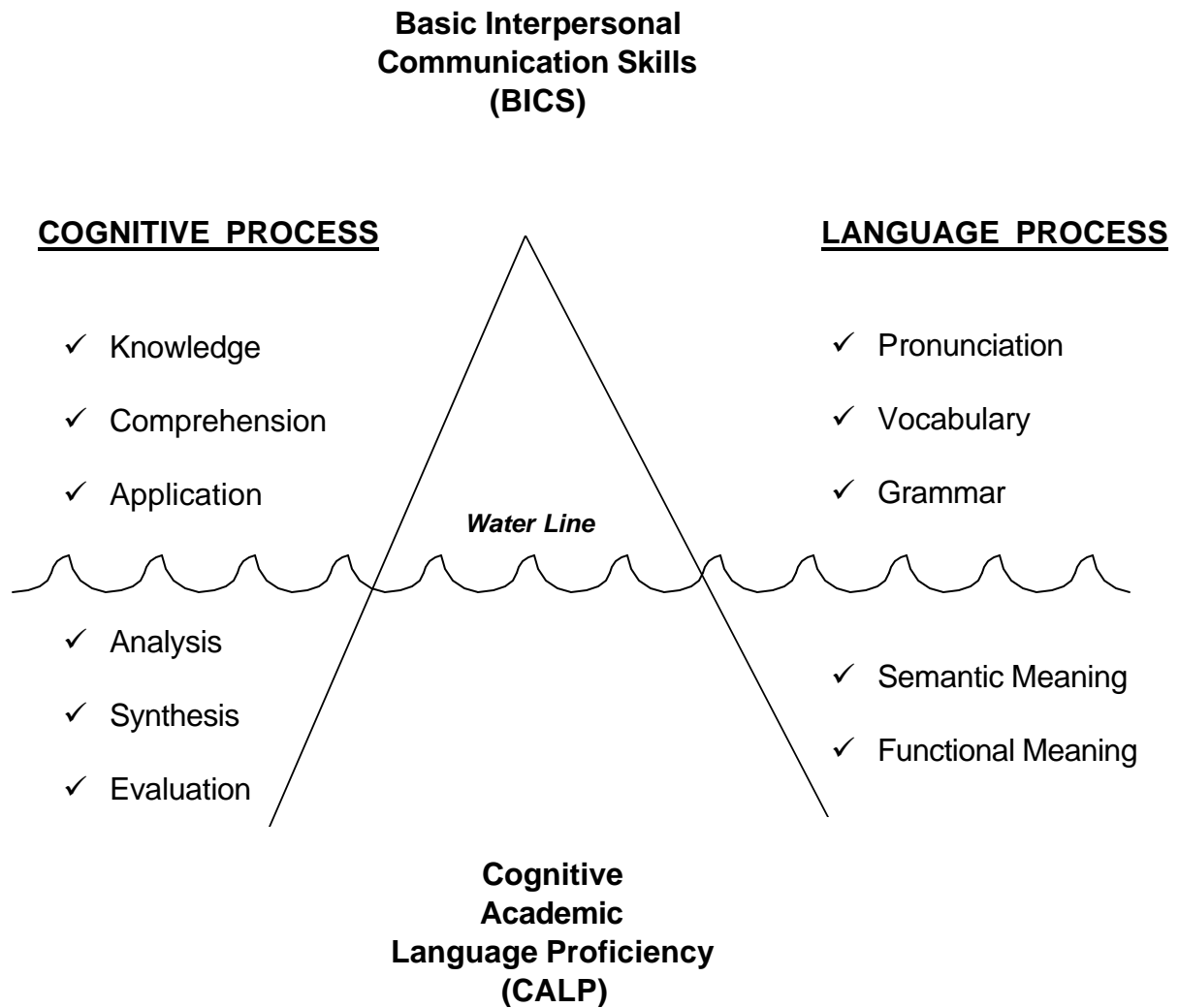


Figure 1. Surface and deeper levels of language proficiency

Adapted from: Rosenthal, J.W. (1996). *Teaching Science to Language Minority Students*, p.48. Multilingual Matters LTD with permission from the publisher Taylor & Francis.

Cummins' (1981) contends that all children develop basic interpersonal communicative skills (BICS) and learn to communicate in their native or first language and that cognitive-academic language proficiency (CALP) reflects a combination of language proficiency and cognitive processes that determines a student's success in school.

#### Contextual support and Cognitive Processes for learning Science

According to Cummins (1980, 1981), Krashen and Biber (1987), Rosenthal (1996), and Spurlin (1995), CALP is the type of language proficiency needed to read textbooks, to participate in dialogue and debate, and to respond to in writing tests. Cognitive academic language proficiency (CALP) enables the student to learn in a context, which relies heavily on oral explanation of abstract or decontextualized ideas. This is often the context in which high school science is taught, with unfamiliar events or topics being described to students with little or no opportunity to negotiate shared meaning (Rosenthal, 1996). According to Chamot and O'Malley (1986), Cummins (1982) and Rosenthal (1996), students who have not yet developed their cognitive academic language proficiency (CALP) will be at a disadvantage in such settings.

Spurlin (1995) adapted Cummins' model, to explain in part, the academic performance in science of Hispanic English language learners (See Figure 2 below).

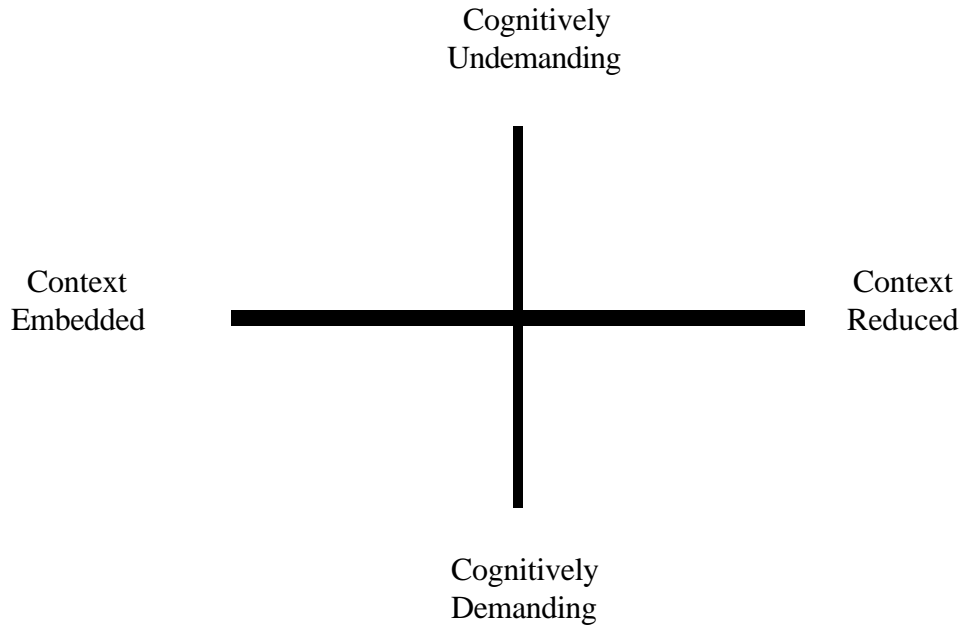


Figure 2. Range of contextual support and degree of cognitive demand

Adapted from: Spurlin, Q. (1995). Making Science Comprehensible for Language Minority Students. Vol. 6 (2), pp. 71-78. Journal of Science Teacher Education.

The horizontal continuum deals with the degree of contextual support available for meaning making and ranges from context embedded to context reduced. Context-embedded communication occurs when language is supported by meaningful concrete, visual cues, and when students and teachers together can negotiate meaning for example, by means of feedback or any other form of communication (Spurlin, 1995). At the other end of the continuum is the context-reduced communication, which depends on linguistic cues for meaning.

The vertical continuum deals with at the top, the tasks or activities in which students have mastered the language necessary to perform them. These tasks or activities are considered to be cognitively undemanding. The bottom of the continuum, on the other hand,

represents activities that are cognitively demanding, because they require language skills that have not been mastered (Spurlin, 1995).

In schools, the language used in science lessons is often context reduced or decontextualized. In other words, the events or topics being described to the student are unfamiliar and there is little or no opportunity to negotiate shared meaning (Rosenthal, 1996). Presenting a new scientific concept to a high school student according to Rosenthal is an example of context reduced language because the information presented may be abstract and unrelated to the students' everyday activities or life experience.

Lawson et al. (1989, 1991) on the other hand, suggested that the acquisition of declarative knowledge "is very much a constructive process which makes either implicit or explicit use of the procedural knowledge" (p. 27). Although both declarative and procedural forms of knowledge can coexist side by side, it is procedural not declarative knowledge that governs the skilled performance and is of central importance in science and in creative and critical thinking (Anderson, 1993; Burmester, 1952; Lawson et al., 1989). For Lawson et al. (1991), "the acquisition of domain-specific conceptual knowledge that is, declarative knowledge, requires the use of general procedural knowledge" (p. 968). More specifically, Lawson et al. (1991) hypothesized that use of a general pattern of some form of formal reasoning (i.e., hypothetico-deductive) is necessary for the acquisition of novel domain specific concepts. Lawson et al. (1991) tested this hypothesis on over 300 high school students participating in biology, chemistry and physics classes.

After determining whether the students were skilled in the use of hypothetico-deductive reasoning, Lawson et al. (1991) classified the students as intuitive, transitional, or reflective thinkers.

The integration of both Cummins' theoretical framework and Lawson et al. research studies, therefore, provided the researchers with an excellent groundwork to examine the potential effects of the linguistics proficiency and cognitive reasoning skills of Hispanic English language learners and native English language speaking students during their acquisition of science content knowledge.

### Design and Methodology

Despite the vast number of studies on factors influencing the academic performance of ethnic and linguistic minority students, investigation of the effects of two very important factors, English language proficiency and scientific reasoning skills, on the acquisition of science content knowledge of Hispanic English language learners is a relatively neglected research area. This research study examined these two factors, English language proficiency and scientific reasoning skills, and provides some empirical evidence for addressing the following questions and their respective hypotheses:

### Research Questions and Hypotheses

What are the effects of English language proficiency and levels of scientific reasoning skills on the acquisition of science content knowledge by Hispanic English language learners participating in Grade 10 science classes?

## Hypotheses

H1A<sub>0</sub>: High school Hispanic English language learners in Grade 10 classified, as having low English language proficiency will score the same on a statewide-standardized science test as high school Hispanic English language learners in Grade 10 classified as having high English language proficiency.

H1B<sub>0</sub>: High school Hispanic English language learners in Grade 10 classified as possessing intuitive reasoning skills will score the same on a statewide-standardized science test as high school Hispanic English language learners in Grade 10 classified as possessing reflective reasoning skills.

H2A<sub>0</sub>: There will be no interaction between English language proficiency and scientific reasoning skills that will influence the academic performance of students (i.e., Hispanic English language learners and native English language speaking students) on a statewide-standardized science test.

## Location, Population and Sample

The subject pool identified for the study consisted of 380 students from a high school located in an urban city in the northeastern part of the United States. These students were Hispanic English language learners and native English language speaking students enrolled in tenth grade earth science, biology and chemistry classes. The actual number of subjects (N = 158) for this study is the balance of students remaining after all of the criteria for the data collection were met. The criteria for the data collection consisted of the subjects meeting the research study requirements for English language proficiency, students' native language (i.e.

English or Spanish), students' reasoning skill levels, and the students' science achievement or scores in a Statewide-standardized science and technology test.

The city has experienced significant population changes in the last 10 years, growing from a total population of 63,000 to approximately 70,000 (U.S. Census, 1990). In the city, Hispanics have become the majority of the new immigrants. At the time of this study, about 77% of the student population in the public school system were classified as Hispanics from either the Dominican Republic or Puerto Rico or other South and Central American countries. A large percentage of the Hispanic students are taught through special English language programs or receive continuing English support in a special transitional bilingual education.

#### Procedures and Instrumentation

An ex post facto research study design was utilized to investigate the effects of English language proficiency and levels of scientific reasoning skills on the acquisition of science content knowledge of the group of Hispanic English language learners and native English language speaking students in Grade 10. Once the language assessment and scientific reasoning skills tests were administered to the students, they were categorized in groups that were known to differ on the following characteristics, English language proficiency, scientific reasoning skills and native language. The study was conducted in four phases over a period of approximately 12 weeks as described below.



### Phase I

The first phase of the study involved the identification of a group of Hispanic English language learners and native English language speaking students enrolled in tenth grade earth science, biology and chemistry classes. Prior to beginning the data collection process, some information (i.e., student ID number, gender, birth date and place, grade level and student home language) was gathered for all the students participating in the study. Based on some of these data, the researchers classified the students as belonging to one of two groups: Hispanic English language learners or native English language speaking students.

### Phase II

The language proficiency of the students was measured through the use of the Test of English as a Foreign Language (TOEFL) instrument. The English language proficiency variable was composed of three levels (i.e., low, intermediate, or high). The students were classified in either one of these levels as determined by their scores in the TOEFL test. The Educational Testing Service (ETS) developed the TOEFL instrument. The test is composed entirely of multiple-choice questions with four possible answers per question (ETS, 1995). There are three sections in the test, each measuring a critical skill in the use of English. These three sections are: Listening comprehension, Structure and written expression and Reading comprehension.

### Phase III

During the third phase of the study, a classroom test of scientific reasoning skills (Lawson, 1978; Lawson, Abraham & Renner, 1989; Lawson, 1990) was administered to both the group of Hispanic English language learners and native English language speaking students participating in tenth grade earth science, biology and chemistry classes. The classroom test of

scientific reasoning consisted of 12 items and involved the testing of students in various tasks ranging from the conservation of weight, volume displacement, control of variables, propositional reasoning, probabilistic reasoning, to the combinatorial and correlational reasoning. The test is designed in a “two-stage” multiple-choice format using diagrams to illustrate problem contexts (Lawson, 1978).

Based on the students’ responses on the tasks in the Lawson test, Hispanic English language learners and native English language speaking students scoring from 0-3 on the test were categorized as intuitive thinkers while students scoring from 4-7 were categorized as transitional. Students scoring from 8-12 in the test were categorized as reflective thinkers. The classroom test of scientific reasoning instrument has been proven to be capable of measuring concrete and formal operational reasoning of secondary school and college students (Lawson, 1978). The instrument was designed with a large number and variety of problems to assure a high degree of reliability. The test reliability was reported to be 0.78.

The classroom test of scientific reasoning was also translated into Spanish. A panel of two experienced high school teachers and one university professor representing the ethnic groups of the students in the study was used to verify the face validity of the Spanish translated version of this test. Once the face validity was verified, the test was administered to the Hispanic English language learners participating in the study whose score in the TOEFL test were low or intermediate and whose home spoken language was Spanish. By using this Spanish version of the classroom test of scientific reasoning, the researchers sought to examine the levels of

scientific reasoning skills of the students in their native or primary language, Spanish. Once this determination was accomplished, the researchers proceeded to investigate the effects, if any, of the levels of scientific reasoning skills of these students on their acquisition of science content knowledge.

#### Phase IV

To examine each student's ability to acquire science content knowledge, this study employed the 1999 Grade 10 Massachusetts Comprehensive Assessment System (MCAS), a statewide-standardized science and technology test. The Grade 10 standardized science test is designed to measure the performance of students on the science and technology academic learning standards contained in the State's Curriculum Frameworks. The student test booklets included three separate science and technology test sessions with a total of thirty-six (36) multiple choice and six (6) open response questions. The questions in the Grade 10 MCAS science and technology test included material from the areas of: position and motion of objects, structure of matter, Ecosystems, interactions of substances, solar system and universe, Earth's processes, heredity and evolution, characteristics of organisms, energy and analysis and interaction of data.

#### Analysis of Data and Results

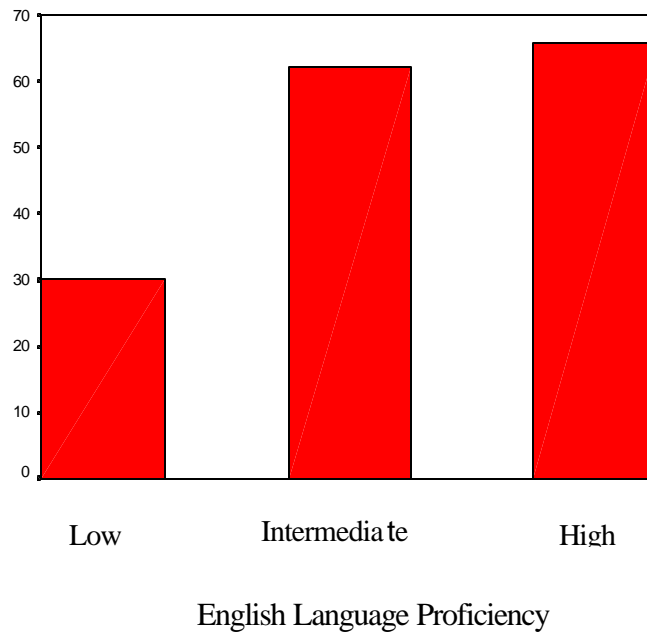
A 3 x 3 x 2 between-subjects factorial design was employed to evaluate the hypotheses in this study (Keppel, 1991; Myers & Well, 1995; Sheskin, 1997). The factorial design was employed to evaluate simultaneously the effect of the three independent variables (i.e., English language proficiency, scientific reasoning, and language learners) on the dependent variable (i.e., scientific content knowledge). The English language proficiency comprised three levels (i.e. low,

intermediate, or high), as did the scientific reasoning variable (i.e., intuitive, transitional, or reflective). The language learner's variable comprised two levels (i.e., Hispanic English language learners or native English language speaking students). The scientific content knowledge variable was a scale variable, reflecting the test scores of the students on the Grade 10 standardized science test. A three-way analysis of variance (ANOVA) for this factorial design allowed the researchers not only to evaluate whether or not there was a three-way interaction ( $p \times r \times l$ ) among the three independent variables on the scientific achievement of high school Hispanic English language learners and native English language speaking students, but also to analyze the three subsumed two-way interactions (i.e.,  $p \times r$ ,  $p \times l$ , and  $r \times l$ ) and the three main effects (i.e.,  $p$ ,  $r$ ,  $l$ ).

Descriptive data and frequency histograms for the independent variables (i.e., English language proficiency, Scientific reasoning skill levels, and Language learners) and the dependent variable (i.e., scores on the MCAS science and technology test) are shown in Figures 3.1a, 3.1b, 3.2a, 3.2b, 3.3a and 3.3b respectively.

### English Language Proficiency

Categories	Frequency
low	30
intermediate	62
high	66
Total	158

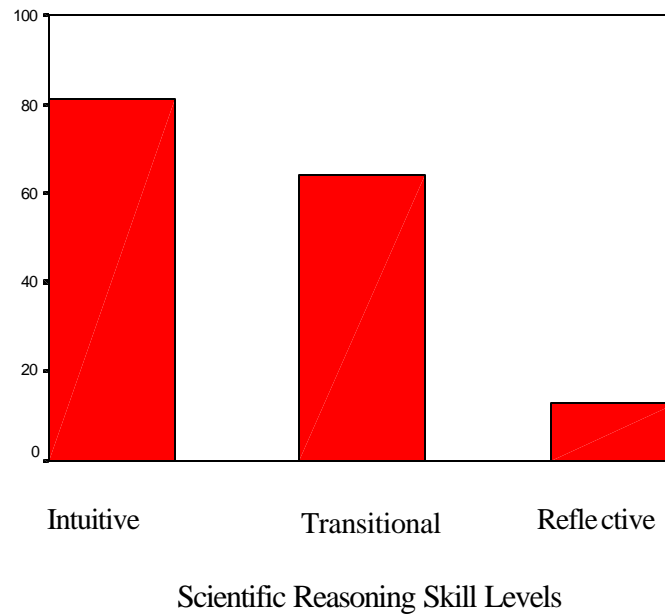


Figures 3.1a and 3.1b:

Frequency distribution for English language proficiency levels as measured by TOEFL (N=158)

### Scientific Reasoning Levels

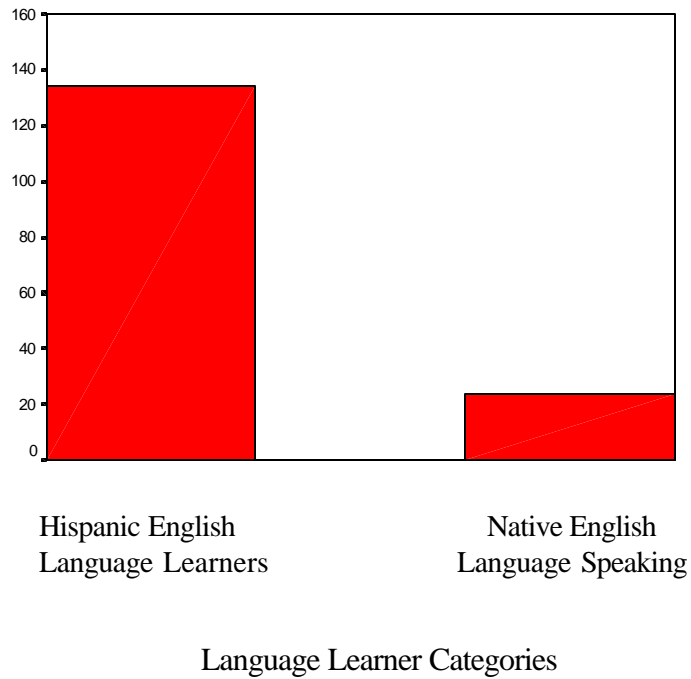
Categories	Frequency
intuitive	81
transitional	64
reflective	13
Total	158



Figures 3.2a and 3.2b: Frequency distribution for Scientific reasoning skill levels as measured by Lawson's instrument (N=158)

### Language Learners

Categories	Frequency
Hispanic English language learner	134
Native English language speaking student	24
Total	158



Figures 3.3a and 3.3b: Frequency distribution for Language learner categories (N=158)

For the 3 x 3 x 2 ANOVA, the researchers first tested the interaction between all of the variables. The results of the 3-way analysis of variance are shown in Table 1 below. The results of the 3-way analysis of variance showed no significant 3-way interaction between the variables in the study. Table 1, shows an *F* ratio of 1.160 and a significance of .283 for the interaction of English language proficiency, levels of reasoning skills, and language learners with regard to the students' performance on the standardized science test.



Table 1

## 3-way Analysis of Variance (N=158)

Dependent Variable: MCASRAW

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4817.072 <sup>a</sup>	13	370.544	13.896	.000
Intercept	12962.437	1	12962.437	486.120	.000
PROFIECI	139.889	2	69.944	2.623	.076
REASONER	573.443	2	286.722	10.753	.000
LANLEARN	2.662	1	2.662	.100	.752
PROFIECI * REASONER	359.168	3	119.723	4.490	.005
PROFIECI * LANLEARN	59.794	2	29.897	1.121	.329
REASONER * LANLEARN	45.710	2	22.855	.857	.427
PROFIECI * REASONER * LANLEARN	30.936	1	30.936	1.160	.283
Error	3839.770	144	26.665		
Total	78545.000	158			
Corrected Total	8656.842	157			

a. R Squared = .556 (Adjusted R Squared = .516)

Subsequent to the analysis of the 3-way interaction, the researchers examined the next order of interactions that is, the three 2-way interactions. As shown in Table 1, only one 2-way interaction was determined to be significant (i.e., English language proficiency  $\times$  reasoning skill). Specifically, Table 1 shows an  $F$  ratio of 4.490 with a significance level ( $Sig$ ) of .005 for the interaction between English language proficiency and reasoning skills. The other 2-way interactions (i.e., English language proficiency  $\times$  Language Learner or Scientific reasoning skills  $\times$  Language Learner) showed no significance at the .05 alpha levels.

The lack of a significant 3-way interaction means that the results of the present study can be safely interpreted by considering the three independent variables two at a time, rather

than all three simultaneously (Keppel, 1991). Therefore, for the present study, the 3-way design was collapsed into less complex 2-way designs for analysis and interpretive purposes. At this point, the researchers assessed the three 2-way interactions and since the interaction of English language proficiency and scientific reasoning skills variables was the only one found to be significant, the researchers proceeded to examine the simple effects of one of the variables, with the other held constant. In addition, because the other 2-way interactions (i.e., English language proficiency  $\times$  Language Learner or Scientific reasoning skills  $\times$  Language Learner) were found not to be significant, the researchers proceeded to examine the main effects of the two independent variables.

#### Analyzing the Simple Effects

As noted previously, a 2-way interaction (i.e., English language proficiency  $\times$  Scientific reasoning skills) meant that the simple effects of one of the variables depended on the levels of the other variables. Thus, because the interaction of these two variables was the only one found to be significant, the researchers proceeded to evaluate the significance of the simple effects. If the English language proficiency variable had been found to be significant, the researchers would have proceeded to examine the various simple comparisons relevant to this manipulation. As Table 1 indicated, the English language proficiency variable did not quite meet the significance ( $Sig. = .076$ ) threshold at the .05 alpha levels.

### Analyzing the Main Effects

Since the 3-way interaction was found not to be significant, the researchers' interest focused on the lower order effects. As noted already, the researchers' interest shifted to the only 2-way interaction (i.e., English language proficiency  $\times$  Scientific reasoning skills) found to be significant. The presence of this interaction however, created some difficulties for interpreting either main effect of the two interacting variables. Nevertheless, the researchers analyzed and safely interpreted the non-interacting main effect. In examining the main effect for the three individual variables as shown in Table 1, only one variable (i.e., reasoning skills) was deemed to be significant at the .05 alpha levels. Specifically, Table 1 reveals an  $F$  ratio of 10.753 with a significance level ( $Sig$ ) of .000 for reasoning skills. Although the significance level ( $Sig$ ) of .076 for English language proficiency does not quite meet the desired alpha level of .05, it suggests though, that English language proficiency may, in fact, contribute significantly to learning science subject matter. Therefore, it is safe to assert that the significant interaction of English language proficiency and scientific reasoning skills variables also suggest that the main effect of the language learner variable could be interpreted unambiguously. In other words, the language learner variable did not have a significant main effect (see Table 1) nor was it involved in any of the 2-way interactions.

As shown in Table 1, the language learner variable was found not to play a significant role at any level in the 3-way analysis of variance. Specifically, the language learner variable did not have a significant main effect, it was not involved in any significant 2-way interaction, nor did it contribute to a significant 3-way interaction. It is as if this variable did not exist in this study. Consequently, the language learner variable was eliminated from further analysis. The 2-way

ANOVA thus, included only English language proficiency and reasoning skills as the two remaining variables for the analysis. The results of the 2-way ANOVA are presented in the following section.

It is important to point out however that, had there been a significant 3-way interaction, any conclusion(s) regarding the 2-way interactions and the main effects was to be treated as inconclusive by the presence of the higher order interaction (Keppel, 1991). However, as indicated previously since the 3-way interaction for the present study was found not to be significant, the researchers considered the 2-way interactions directly without ambiguity. Hence, with a non-significant 3-way interaction, the design as noted earlier, for all practical purposes, became a 2-factor design.

#### Results of the 2-way Factorial Analysis of Variance (ANOVA)

The categories and descriptive statistics for English language proficiency and reasoning skill levels for all the subjects in the sample (i.e., Hispanic English language learners and native English language speaking students) used for the 2-way analysis of variance are shown in Tables 2 and 3 below. Table 2 shows the number of students in various categories of English language proficiency and reasoning skills. For English language proficiency, thirty (30) students were categorized as having low English language proficiency, sixty-two (62) as having intermediate and sixty-six (66) as having high proficiency. For the reasoning skills variable, eighty-one (81) students were classified as having intuitive reasoning skills while sixty-four (64) and thirteen (13) were categorized as having transitional or reflective reasoning skills, respectively.

Table 2

Categories and Sample sizes for English language proficiency and reasoning skill levels for all the subjects (N = 158)

		Categories	N
Language Proficiency	1	low	30
	2	intermediat	62
	3	high	66
Reasoning Levels	1	intuitive	81
	2	transitional	64
	3	reflective	13

Table 3 below, shows the total number of subjects in the sample to be 158 (N = 158). The first row in Table 3 shows the total average score on the standardized science test for students classified as having low English language proficiency to be 14.97. In the second row, the total average score on the standardized science test for students classified as having intermediate English language proficiency is shown to be 18.15. The total average score on the standardized science test for students classified as having high English language proficiency is shown to be 26.50 (see Table 3).

Table 3

Descriptive statistics for English language proficiency and Reasoning skill levels for Language Learners (N = 158)

Dependent Variable: MCASRAW				
Language Proficiency:	Reasoning Level:	Mean	Std. Deviation	N
low	intuitive	15.12	3.09	26
	transitional	14.00	10.13	4
	Total	14.97	4.36	30
intermediate	intuitive	17.33	5.24	43
	transitional	19.06	5.33	18
	reflective	37.00	.	1
	Total	18.15	5.77	62
high	intuitive	20.58	5.68	12
	transitional	26.86	5.06	42
	reflective	31.17	5.94	12
	Total	26.50	6.18	66
Total	intuitive	17.10	4.99	81
	transitional	23.86	6.93	64
	reflective	31.62	5.91	13
	Total	21.03	7.43	158

The first row in Table 3 also shows that the average score on the standardized science test for students classified as having low English language proficiency and intuitive reasoning skills was better (mean = 15.12) than for the students classified as having low English language proficiency and transitional reasoning skills (mean = 14.00).

The second row in Table 3 shows the average score on the standardized science test

for the students classified as having intermediate English language proficiency and intuitive reasoning skills to be 17.33. The data shows that students with intermediate English language proficiency and transitional reasoning skills scored better (mean = 19.06) on the standardized science test than those students classified as having intermediate English language proficiency and intuitive reasoning skills (mean = 17.33). Also in the second row of Table 3, students classified as having intermediate English language proficiency and reflective reasoning skills scored better (mean = 37.00) on the standardized science test than those students classified as having intermediate English language proficiency and either intuitive or transitional reasoning skills.

In the third row of Table 3, the average score on the standardized science test for students classified as having high English language proficiency and intuitive reasoning skills are shown to be 20.58. Table 3 also shows the average scores on the standardized science test for students classified as having high English language proficiency and transitional or reflective reasoning skills to be 26.86 and 31.17, respectively.

Finally, Table 3 shows the total average scores on the standardized science test for students classified as having intuitive reasoning skills (total mean = 17.10), students classified as having transitional reasoning skills (total mean = 23.86) and students classified as having reflective reasoning skills (total mean = 31.62). The data clearly shows that students classified as having high English language proficiency and transitional (mean = 26.86) or reflective reasoning skills (mean = 31.17) scored better on the standardized science test than students classified as having low English language proficiency and intuitive reasoning skills (mean =

20.58). The 2-way interaction was examined further by conducting an analysis of variance (ANOVA).

The results of the analysis of variance (ANOVA) are shown in Table 4 below. Table 4 shows a ratio of means squares (*F*) of 3.865 and a significance level (*Sig*) of .011 or less than .05 for the first-order interaction of the English language proficiency and reasoning skills variables. The ANOVA clearly showed an interaction between these two independent variables with regard to the students' performance on the standardized science test.

Table 4

2-Way Analysis of Variance (ANOVA)

Dependent Variable: MCASRAW

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4684.075 <sup>a</sup>	7	669.154	25.265	.000
Intercept	16129.180	1	16129.180	608.990	.000
PROFIECI	506.097	2	253.049	9.554	.000
REASONER	701.232	2	350.616	13.238	.000
PROFIECI * REASONER	307.128	3	102.376	3.865	.011
Error	3972.766	150	26.485		
Total	78545.000	158			
Corrected Total	8656.842	157			

a. R Squared = .541 (Adjusted R Squared = .520)

An examination of the main effects of the two variables (i.e., English language proficiency and scientific reasoning skills) also revealed that each variable individually contributed significantly to the students' performance on the standardized science test.



Specifically, for English language proficiency Table 4 shows an  $F$  ratio of 9.554 with a significance level ( $Sig$ ) of .000; and, an  $F$  ratio of 13.238 with a significance level ( $Sig$ ) of .000 shown for reasoning skills. While the results of the 3-way ANOVA only suggested that English language proficiency might have significantly contributed to the students' performance on the standardized science test, this 2-way ANOVA definitely highlighted English language proficiency as a significant contributor to the students' performance on the standardized science test.

In addition, it is noted that the essentially equal adjusted  $R$ -squared values for the two analyses of variance (see notes in Tables 1 and 4) indicated that both the three-variable model and the two-variable model accounted for the same amount of variance. However, the principle of parsimony would prefer the two-variable model over the three-variable model; thus, supporting the elimination of the third variable (i.e., language learner) and the collapsing of the 3-way ANOVA into the 2-way ANOVA.

### Results of the Statistical Tests of Hypotheses

The hypotheses developed and examined for this study are related to either Cummins' theoretical framework on cognitive academic language proficiency and/or Lawson et al. research studies on scientific reasoning skills. As previously noted, the researchers evaluated the hypotheses using a between-subjects factorial analysis of variance (ANOVA). The following hypotheses were developed to examine Cummins' claim on the need for students to have cognitive academic language proficiency as a prerequisite to learning science content subject matter.

*Null Hypothesis  $H1A_0$* : With respect to English language proficiency ( $p$ ). Hispanic English language learners in Grade 10 classified as having low English language proficiency will score the same on a standardized science test as Hispanic English language learners in Grade 10 classified as having high English language proficiency.

*Alternative Hypothesis  $H1A_1$* : With respect to English language proficiency ( $p$ ). Hispanic English language learners in Grade 10 classified as having low English language proficiency will not score the same on a standardized science test than Hispanic English language learners in Grade 10 classified as having high English language proficiency.

The descriptive statistics for the independent variable English language proficiency and average scores on the standardized science test for the group of Hispanic English language learners used for testing the null hypothesis  $H1A_0$  are shown in Table 5 below. Table 5, shows the total number of Hispanic English language learners in the sample to be 134 ( $n = 134$ ). Twenty-eight (28) students were classified as having low English language proficiency, fifty-four (54) as having intermediate English language proficiency and fifty-two (52) as having high English language proficiency. Table 5 also shows the average scores on the standardized science test obtained by Hispanic English language learners classified as having low, intermediate, or high English language proficiency. The results in Table 5 below show the average score on the standardized science test to be lower for Hispanic English language learners with low English language proficiency (mean = 14.86) than for Hispanic English language learners with high English language proficiency (mean = 26.92).

Table 5

Descriptive Statistics for English language proficiency levels and average Science Test

Scores for Hispanic English language learners (n = 134)

MCASRAW			
	N	Mean	Std. Deviation
low	28	14.86	4.49
intermediate	54	18.04	6.06
high	52	26.92	6.03
Total	134	20.82	7.61

The descriptive statistics suggest that there were differences in the average scores on the standardized science test between the two groups of Hispanic English language learners. The null hypothesis ( $H1A_0$ ) stipulated however, that the average test scores for the two groups were the same. In testing the null hypothesis  $H1A_0$ , the researchers used an analysis of variance (ANOVA) technique.

The ANOVA technique tested the null hypothesis ( $H1A_0$ ) that the sample means or students' average scores on the standardized science test were equal. The results of the analysis of variance (ANOVA) are shown in Table 6 below. Table 6 shows a ratio of means squares ( $F$ ) of 50.510 and a significance level ( $Sig$ ) of .000; that is, the probability of obtaining an  $F$  ratio of that magnitude or larger is approximately zero when the null hypothesis is true. Hence, the null hypothesis ( $H1A_0$ ) was rejected for it was unlikely that the average scores on the

standardized science test were the same for the group of Hispanic English language learners with three different levels of English language proficiency.

Table 6

Analysis of Variance (ANOVA) for Hypothesis H1A<sub>0</sub>

MCASRAW					
	Sum of Squares	df	Mean Square	F	Sig.
Between Group:	3350.655	2	1675.327	50.510	.000
Within Groups	4345.047	131	33.168		
Total	7695.701	133			

Although the statistically significant *F* ratio shown in Table 6 above indicates that it appears unlikely that all average scores on the standardized science test are equal, it does not indicate which groups were different from each other. In addition to performing an ANOVA test, the researchers examined the equality or homogeneity of variance assumption by conducting a Levene test. The equality or homogeneity of variance assumption evaluates whether there is evidence to indicate that an inequality exists between the variances of the population represented by the two samples under study (Sheskin, 1997). The Levene test thus, was conducted to test that the two samples came from populations with the same variances. The Levene test showed equality or homogeneity of variances. Hence, multiple comparisons were performed using the Tukey's technique. The results of the test of homogeneity are shown in Table 7 below followed by a discussion of the results of the Tukey's multiple comparisons.

Table 7

Test of Homogeneity of Variance

MCASRAW			
Levene Statistic	df1	df2	Sig.
1.115	2	131	.331

With the results of the ANOVA (see Table 6) and the Levene test showing homogeneity of variance (see Table 7), the researchers conducted the planned multiple comparisons by using the Tukey's HSD, Scheffé and Bonferroni procedures. Table 8 shows the average scores on the standardized science test and the group sizes for the various levels of English language proficiency for Hispanic English language learners. In this section, only the results of the Tukey's HSD multiple comparisons are shown in Tables 8 and 9 below.

Table 8

Average Science Test Scores for Hispanic English Language Learners

Tukey HSD<sup>a,b</sup>

Language Proficiency	N	Subset for alpha = .05		
		1	2	3
low	28	14.86		
intermediate	54		18.04	
high	52			26.92
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.837.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Ty error levels are not guaranteed.

Table 9.

Tukey's Multiple Comparisons

Dependent Variable: MCASRAW

Tukey HSD

(I) Language Proficiency	(J) Language Proficiency	Mean		Sig.
		Difference (I-J)	Std. Error	
low	intermediate	-3.18*	1.34	.047
	high	-12.07*	1.35	.000
intermediate	low	3.18*	1.34	.047
	high	-8.89*	1.12	.000
high	low	12.07*	1.35	.000
	intermediate	8.89*	1.12	.000

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

The first row in Table 9 above corresponds to a comparison of two groups, Hispanic English language learners classified as having low English language proficiency to the Hispanic English language learners classified as having intermediate or high English language proficiency. The last row shows the comparisons of the group of Hispanic English language learners classified as having high English language proficiency to the group of Hispanic English language learners classified as having low or intermediate English language proficiency. The difference in average science test scores between the two groups (i.e., Hispanic English language learners with low English language proficiency and Hispanic English language learners with high English language proficiency) is shown to be significant at the .05 levels. The pairs of average scores that are significantly different from each other are shown in Table 9 with an asterisk. All possible pairs of groups are shown twice in Table 9. The observed significant level of the test of the null hypothesis ( $H1A_0$ ) that the two groups (i.e., Hispanic English language learners in Grade 10 classified as having low English language proficiency and Hispanic English language learners in Grade 10 classified as having high English language proficiency) came from populations with the same average scores on the standardized science test is shown in the column labeled *Sig* in Table 9. The observed significance level for this pair is shown to be .000 or less than .05. In fact, the observed significance levels for all the pairs are shown to be less than .05.

Therefore, based on the data collected and on the results of the data analysis it is appropriate to reject the null hypothesis ( $H1A_0$ ) which asserted that Hispanic English language learners in Grade 10 classified as having low English language proficiency scored the same on the standardized science test as Hispanic English language learners in Grade 10 classified as

having high English language proficiency. In turn, the alternative hypothesis ( $H1A_1$ ) which asserted that Hispanic English language learners in Grade 10 classified as having low English language proficiency will not score the same on the standardized science test than Hispanic English language learners in Grade 10 classified as having high English language proficiency was supported by the data.

To test the findings put forth by Lawson and his colleagues regarding the need for having formal patterns of reasoning as a prerequisite for learning science subject matter, the researchers developed the following hypotheses.

***Null Hypothesis  $H1B_0$ :*** With respect to reasoning skills ( $r$ ). Hispanic English language learners in Grade 10 classified as possessing intuitive reasoning skills score the same on a standardized science test as Hispanic English language learners in Grade 10 classified as possessing reflective reasoning skills.

***Alternative Hypothesis  $H1B_1$ :*** With respect to reasoning skills ( $r$ ). Hispanic English language learners in Grade 10 classified as possessing intuitive reasoning skills will not score the same on a standardized science test than Hispanic English language learners in Grade 10 classified as possessing reflective reasoning skills.

The descriptive statistics for the levels of reasoning skills for Hispanic English language learners and their average scores on the standardized science test used for testing the null hypothesis  $H1B_0$  are shown in Table 10 below. Table 10, shows the total number of Hispanic English language learners in the sample to be 134 ( $n = 134$ ). Seventy-five (75) students were



classified as having intuitive reasoning skills, forty-seven (47) as having transitional reasoning skills and twelve (12) as having reflective reasoning skills. Table 10 also shows the average scores on the standardized science test obtained by Hispanic English language learners in the various levels of reasoning skills. The data in Table 10 show the average score on the standardized science test to be lower for Hispanic English language learners with intuitive reasoning skills (mean = 17.03) than for Hispanic English language learners with reflective reasoning skills (mean = 31.42).

Table 10

Descriptive statistics for reasoning skill levels and average Science Test Scores for Hispanic English language learners. (n = 134)

MCASRAW			
	N	Mean	Std. Deviation
intuitive	75	17.03	5.10
transitional	47	24.17	7.23
reflective	12	31.42	6.13
Total	134	20.82	7.61

The descriptive statistics shown in Table 10 suggest that there are differences in the average scores on the standardized science test between the group of Hispanic English language learners classified as having intuitive reasoning skills and the group of Hispanic English language learners classified as having reflective reasoning skills. As noted, the null hypothesis ( $H1B_0$ ) stipulated that the average test scores on the standardized science test for the three groups were the same while the alternative hypothesis ( $H1B_1$ ) indicated that there was a difference.

The researchers once again, used an analysis of variance (ANOVA) technique to test the null hypothesis  $H1B_0$ . The ANOVA technique tested the null hypothesis ( $H1B_0$ ) that the average test scores on the standardized science test for the groups were equal. The results of the analysis of variance (ANOVA) are shown in Table 31 below. Table 11 shows a ratio of means squares ( $F$ ) of 40.810 and a significance level ( $Sig$ ) of .000; which means that the probability of obtaining an  $F$  ratio of that magnitude or larger is approximately zero when the null hypothesis is true. Hence, the null hypothesis ( $H1B_0$ ) was rejected for it is unlikely that the average scores on the standardized science test were the same for the group of Hispanic English language learners classified as having intuitive reasoning skills and the group of Hispanic English language learners classified as having reflective reasoning skills.

Table 11

Analysis of Variance (ANOVA) for Hypothesis  $H1B_0$

MCASRAW					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2954.200	2	1477.100	40.810	.000
Within Groups	4741.502	131	36.195		
Total	7695.701	133			

A Levene test was also conducted to examine the equality of variances. The results of the Levene test were significant and showed an inequality or non-homogeneity of variances as presented in Table 12 below.

Table 12

Test of Homogeneity of Variance

MCASRAW			
Levene Statistic	df1	df2	Sig.
4.561	2	131	.012

Since the Levene test showed inequality of variances as noted earlier, multiple comparisons were performed using the Tamhane technique. The Tamhane technique is a conservative pairwise comparison test based on a *t* test and it is frequently used when the variances are unequal or non-homogeneous. The results of the Tamhane multiple comparisons are shown in Table 13 below.

Table 13

Tamhane Multiple Comparisons

Dependent Variable: MCASRAW

Tamhane

(I) Reasoning Levels	(J) Reasoning Levels	Mean		
		Difference (I-J)	Std. Error	Sig.
intuitive	transitional	-7.14*	1.12	.000
	reflective	-14.39*	1.87	.000
transitional	intuitive	7.14*	1.12	.000
	reflective	-7.25*	1.95	.007
reflective	intuitive	14.39*	1.87	.000
	transitional	7.25*	1.95	.007

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

The first row in Table 13 shows the comparisons between two groups; the group of Hispanic English language learners classified as having intuitive reasoning skills to the group of

Hispanic English language learners classified as having transitional or reflective reasoning skills. The data in Table 13 shows a significant difference on the average science test scores between these two groups at the .05 levels. The observed significance level of the test of the null hypothesis ( $H1B_0$ ) that the two groups (i.e., Hispanic English language learners in Grade 10 classified as having intuitive reasoning skills and Hispanic English language learners in Grade 10 classified as having reflective reasoning skills) came from populations with the same average scores on the standardized science test is shown in the column labeled *Sig* in Table 13. The observed significance level for this pair is shown to be less than .05. Again, pairs of average scores that are significantly different from each other are shown in Table 13 with an asterisk. All possible pairs of groups are shown twice in Table 13. As shown in Table 13, the observed significance levels for all the pairs are less than .05.

Based on the data collected and on the results of the analysis of the data presented above, the null hypothesis ( $H1B_0$ ) that Hispanic English language learners in Grade 10 classified as having intuitive reasoning skills scored the same on the standardized science test as Hispanic English language learners in Grade 10 classified as having reflective reasoning skills was rejected. Conversely, the alternative hypothesis ( $H1B_1$ ) that Hispanic English language learners in Grade 10 classified as having intuitive reasoning skill scored differently on the standardized science test than Hispanic English language learners in Grade 10 classified as having reflective reasoning skills was supported by the data and therefore retained by the researchers.

***Null Hypothesis  $H2A_0$ :*** With respect to English language proficiency ( $p$ ) and

reasoning skills ( $r$ ). There will not be an interaction between English language proficiency and scientific reasoning skills that will influence the scores of the students (i.e., Hispanic English language learners and native English language speaking students) on a standardized science test.

*Alternative Hypothesis H2A<sub>1</sub>*: With respect to English language proficiency ( $p$ ) and reasoning skills ( $r$ ). There will be an interaction between English language proficiency and scientific reasoning skills that will influence the scores of the students (i.e., Hispanic English language learners and native English language speaking students) on a standardized science test.

The data analyses for the interaction of English language proficiency and reasoning skills variables was extensively discussed in the section labeled 2-way ANOVA. Based on the results of the 2-way ANOVA, the researchers proceeded to reject the null hypothesis (H2A<sub>0</sub>), which asserted the absence of an interaction between English language proficiency, and scientific reasoning skills that will influence the scores of the students on a standardized science test. Conversely, the researchers retained the alternative hypothesis (H2A<sub>1</sub>), which asserted the presence of an interaction between English language proficiency and scientific reasoning skills that will influence the scores of the students on a standardized science test was supported by the data collected for the present study.

#### Summary of the Results of the Tests of the Hypotheses

Having completed the data analysis and testing of the hypotheses which dealt with the influences or interactions of the English language proficiency and scientific reasoning skills variables on the academic performance on the standardized science test taken by both groups of Hispanic English language learners and native English language speaking students, the researchers submit the following summary of the tests of the various hypotheses developed for

the present study: 1) Hypothesis H1A<sub>0</sub> was rejected for it was unlikely that the average scores on the standardized science test were the same for the three groups in the sample, 2) Hypothesis H1B<sub>0</sub> was also rejected for it was unlikely that the average scores on the standardized science test were the same for Hispanic English language learners classified as having intuitive reasoning skills and Hispanic English language learners classified as having reflective reasoning skills and 3) Hypothesis H2A<sub>0</sub> was rejected for a significant interaction was present between the English language proficiency and reasoning skills variables.

### Summary of Results

In this study, the researchers tested various hypotheses about means or average scores obtained by a group of students on a standardized science test. The researchers' conclusions about the means or the students' average test scores were based on looking at the variability or standard deviation of sample means. In performing the various analyses of variance (ANOVA), the researchers looked at how much the observed sample means varied. This observed variability were compared to the expected variability when the null hypotheses that all means were the same were true. The data analyses in this study showed that the sample means or students' average test scores varied more than expected resulting in the groups not having the same means. Based on the observed means and standard deviations in the 18 cells, the researchers tested whether, in the sample, the average scores in a standardized science test were the same for subjects with different English language proficiency levels; whether the average scores in a standardized science test were the same for subjects with different levels of

scientific reasoning skills; and whether there was an interaction between all the variables (i.e., English language proficiency, scientific reasoning skills and language learner) which would have influenced the academic performance of the subjects (i.e., Hispanic English language learners and native English speaking students) on a standardized science test scores.

The within-groups estimate of variability found in the study indicated how much the observations within a group varied. Since an analysis of variance (ANOVA) was used as the appropriate statistical technique to conduct the data analysis, an assumption was made that all groups came from samples with the same variance. However, most of the data collected for the study did not exhibit homogeneity of variance nor did it show equality of number of subjects in the samples.

In this study, the decision to accept or reject the null hypotheses was based on comparing the between-groups and the within-groups estimates of variability. In some cases (i.e.,  $H1A_0$ ,  $H1B_0$ , and  $H2A_0$ ), because the between-groups estimates were larger than the within-groups estimates, the researchers proceeded to reject the null hypotheses that all the average test scores in the standardized science test were equal in the sample. The results of the 3-way analysis of variance showed no significant 3-way interaction between the variables in the study. Table 1 showed an  $F$  ratio of 1.160 and a significance of .283 for the interaction of English language proficiency, scientific reasoning skills and language learners variables with regard to the academic performance of the students on the standardized science test. Likewise, there was no significant 2-way interaction between the English language proficiency or the reasoning skill levels and the language learners. Table 1 showed  $F$  ratios of 1.121 and .857 with significant levels of .329 and .427 respectively for these 2-way interactions.

Table 1 however, showed a significant 2-way interaction between the English language proficiency and scientific reasoning skills variables with regard to the students' performance on the standardized science test. The results of this 2-way interaction showed an  $F$  ratio of 4.490 with a significant level of .005. This finding is believed to be important for it implies that combined high levels of English language proficiency and reasoning skills enhance students' abilities to learn science content subject matter. In addition, Table 1 showed a significant main effect for the variable reasoning skills (i.e., an  $F$  ratio of 10.753 with a significant level of .000). No significant main effect was shown in Table 1 for either English language proficiency or language learner.

After collapsing the 3-way factorial design into a 2-way factorial design, the researchers considered the three 2-way interactions. While the results of the 3-way ANOVA only suggested that English language proficiency might have had a small but significant contribution to the students' performance on the standardized science test, the 2-way ANOVA clearly highlighted English language proficiency as a significant contributor to the students' performance on the standardized test. Subsequent analyses of variances (ANOVA) indicated that the 2-way interaction (i.e., English language proficiency  $\times$  reasoning skills) was determined to be significant. Because this 2-way interaction was found to be significant, the researchers proceeded to examine the simple effects of one of the variables with the other held constant. The analyses of the simple interaction consisted of a 2-way analysis of variance (ANOVA) performed on the collected data. The results shown in Table 4 that this 2-way interaction was indeed significant at



the .05 alpha levels. To identify specifically where the significant differences between cells existed, post hoc comparisons were undertaken.

#### Implications of the Results for Theory, Research and Practice

While the results of the 3-way ANOVA only suggested that English language proficiency might have significantly contributed to the students' performance on the Grade 10 standardized science test, the 2-way ANOVA definitely highlighted English language proficiency as a significant contributor to the students' performance on the standardized test. The 3-way ANOVA also showed a significant 2-way interaction between English language proficiency and reasoning skill levels with reference to the students' performance on the standardized science test. This finding is believed to be important for it implies that combined high levels of English language proficiency and reasoning skills enhance students' abilities to learn science content subject matter.

As noted, English language proficiency is presumed to be one important contributor to the unexplained variance of the differences in academic achievement between Hispanic English language learners and native English language speaking students (Canale, 1981; Cummins, 1981, 1991). According to Cummins, high order English language proficiency or cognitive academic language proficiency enables the student to learn in a context, which relies heavily on oral explanation of abstract or decontextualized ideas. This is often the context in which high school science is taught, with unfamiliar events or topics being described to students with little or no opportunity to negotiate shared meaning (Rosenthal, 1996). It has been stated (Chamot & O'Malley, 1986; Cummins, 1982; and Rosenthal, 1996), that students who have not yet

developed higher order English language proficiency or cognitive academic language proficiency will be at a disadvantage in such settings.

Similarly, it has been stated (Lawson & Renner; 1975; and Lawson et al., 1991), that the use of a general pattern of formal reasoning is necessary for the acquisition of new science concepts. Lawson and his colleagues (1991) investigated the hypothesis that the acquisition of domain specific declarative knowledge requires use of general procedural knowledge. More specifically, they hypothesized that use of a general pattern of some form of formal reasoning is necessary for the acquisition of novel domain specific concepts.

The present study examined the effects English language proficiency and levels of scientific reasoning skills and their influence on the performance of a group of Grade 10 Hispanic English language learners and native English language speaking students on a standardized science test. The data collected, analyzed and presented by this study implies that there is perhaps a relationship between English language proficiency, scientific reasoning skills and science content learning. Additional evidence was presented examining the effects of English language proficiency and scientific reasoning skills as factors on the learning of science content knowledge of Hispanic English language learners. The implications here are that both higher order of English language proficiency and scientific reasoning skills were shown to predict success in learning science concepts.

Finally, one of the major implications of this study is perhaps the adoption and/or integration of some portions of both Cummins' theoretical framework and Lawson et al.

research studies into the current schools science curriculum. Well implemented, both of these could be a potential tool to enhance the English language proficiency and cognitive reasoning skills of Hispanic English language learners so as to help them achieve higher academic performance in science content subject matter.

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*About the authors...*

**Hector N. Torres** is on faculty in the Graduate School of Education, University of Massachusetts, Lowell, MA 01863

**Dana L. Zeidler** is on faculty in the Department of Secondary Education, College of Education, University of South Florida, Tampa, FL 33620-5650