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The effects of Spanish English dual language immersion on student achievement in science and mathematics

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Abstract

In this study, we present quantitative findings on the effects of English-Spanish dual language immersion on student achievement in science and mathematics in grades 3, 4, and 5. The research aims to present empirical evidence documenting the impact of dual language immersion, reveal analytical techniques utilizing nonparametric measure of similar and comparative analysis, and discuss the benefits and common misconceptions associated with dual language immersion as well as implications for serving disadvantaged students and their success in STEM education.

Keywords: *dual language immersion, mathematics and science, elementary*

Introduction

The world economy has changed dramatically with the wide availability of digital tools and on-demand access to information. The U.S. President's Council of Advisors on Science and Technology (PCAST, 2010) states, "In the 21st century, the country's need for a world-leading STEM workforce and a scientifically, mathematically, and technologically literate populace has become even greater, and it will continue to grow" (p. vii). In its white paper, The Partnership for 21st Century Skills (2009) argues that educational outcomes for students in the 21st century must focus on communication and collaboration across multiple languages and cultures and the need for learning to promote connections, critical thinking, and creativity within and between content disciplines. Finally, Tochon (2009) argues that given the interconnectedness of the world economy, "monolingual speakers are at competitive disadvantage for a growing number of jobs. …World language fluency is an asset" (p. 656).

Research has shown that when taught by methods that acknowledge and build on students' strengths, promote collaboration, and provide access to meaningful content, all students can learn to problem solve, think critically, and communicate with and about mathematics and science (National Research Council, 2000, 2007; National Science Foundation, 2008). However, not all students have access to such learning opportunities. For example, compared to native English speaking white students, students who are Latino, low income, and/or English language learners (ELLs) have far less exposure to such instruction and significantly fewer opportunities to develop foundational science and mathematics knowledge in elementary and middle schools (Lee & Avalos, 2002; Oakes, 1990; Oakes, Joseph, & Muir, 2004). This opportunity gap can, in part, be attributed to U.S. classroom norms which, historically, have been based on white middle class patterns of interaction, resulting in students from low income and language minority backgrounds encountering a cultural mismatch; the normative ways of thinking, talking, and behaving at school are often not the same as those learned in their home communities (Delpit, 1995; Ladson-Billings & Tate, 1995). This results in feelings of cultural isolation and social detachment among students (Cholewa & West-Olatunji, 2008) and makes it difficult for parents to know how to best support their children's schooling.

The negative impact of these experiences is seen in the achievement data. Nationally, 21% of 4th grade and 17% of 8th grade Hispanic students are proficient in mathematics, compared to 44% and 51% of 4th and 8th grade white students, respectively (The Nation's Report Card, N.D.). These disparities and age-based declines are exacerbated for English language learners (ELLs). A 2005 summary of mathematics achievement showed that nearly half (46%) of 4th grade ELLs and over two-thirds (71%) of 8th grade ELLs scored in the "below basic" category––the lowest level (Fry, 2007). For science, only 34% of 4th grade students, 30% of 8th grade students, and 21% of 12th grade students scored at or above proficient on the National Assessment of Educational Progress. Compared to their non-ELL peers, ELLs underperformed in science with only 5% of 4th grade students and 2% of 8th grade students scoring at or above proficient (National Center for Education Statistics, 2011).

There is a broad research base establishing that dual language education[1], when designed and implemented with the needs of specific learners in mind, leads to positive academic and social outcomes for all students and particularly for English language learners (August & Hakuta 1997; Genesee, Lindholm-Leary, Saunders, & Christian, 2006; Krashen & McField, 2005; Rolstad, Mahoney, & Glass 2005; Thomas & Collier, 2004). Among the few published studies addressing the role of students' home language (L1) and language of schooling (L2) across content areas, most have tended to focus on elementary-school classrooms, and fewer have focused on the learning of mathematics and science (Angelova, Gunawardena, &

[1] While the terms *bilingual* education and *dual language* education get used interchangeably in much of the literature, we are using dual language to refer to the development of content literacy in two languages. This is sometimes referred to as *additive bilingualism* as it seeks to add a second language to the student's first language. For more information, see: http://sites.uci.edu/bilingualteacher/dual-immersion-schools/

Volk, 2006; Fitts, 2006; Rubinstein-Ávila, 2002; Worthy & Rodgríguez-Galindo, 2007).

This paper presents quantitative findings on the effects of English-Spanish dual language immersion on student achievement in science and mathematics in grades 3, 4, and 5. Specifically, it (1) presents empirical evidence documenting the impact of dual language immersion, (2) reveals analytical techniques using nonparametric measure of similar and comparative analysis, and (3) discusses policy implications pertaining to multilingual and multicultural education.

Theoretical Framework

What is Dual Language Immersion?

According to the Center for Applied Linguistics (2011), in *Dual Language Education,* also known as *Dual Language Immersion (DI, DL, DLI),* students are taught literacy and academic content in English and a partner language (e.g., Spanish, Korean, Mandarin). The goal is for students to develop high levels of language proficiency, literacy, academic achievement, and an understanding of diverse cultures in two languages. There are four main types of DLI programs:

1. *Two-way immersion (TWI)*: This term is used interchangeably with DLI and involves a balanced number of native English speakers and native speakers of a partner language. These two language groups are integrated for instruction so that at different times one models a language and one learns a language. The structure of TWI programs varies, but they all provide at least 50% of instruction in the partner language at all grade levels beginning in pre-K, Kindergarten, or first grade and lasting through at least five years (preferably through Grade 12).
2. *Developmental bilingual*: Enroll students who are primarily native speakers of the partner language.
3. *Foreign language immersion*, *language immersion* or *one-way immersion*: Enroll primarily native English speakers.
4. *Heritage language programs*: Enroll students who are dominant in English but whose parents, grandparents, or other ancestors spoke the partner language.

Within these four types of DLI programs, several different models exist:

1. *50/50* model: English and the partner language are each used for 50% of instruction at all grade levels.
2. *90/10* model: Students are instructed 90% of the time in the partner language and 10% in English in the first year or two. English instruction gradually increases each year until English and the partner language are each used for 50% of instruction (e.g., and the program lasts at least 5 years (preferably K-12).
3. *Language division by schedule*: Within any DLI program, students speak in one language at a time, and the times for each language are explicitly

defined. In some schools, language alternates by day, by week, or by several week periods. In other schools, students speak one language in the morning and the other language after lunch. The languages then switch after a designated amount of time (e.g., if English is in the morning and Spanish is in the afternoon, then they switch after three weeks). Further variation includes programs where particular subjects are always taught in one language (e.g., Spanish is only spoken in students' mathematics and science classrooms).

4. *Language division by instructor*: A dual language program may use a *Self-Contained* or *Side-by-Side* model. Self-Contained programs have one teacher for one group of students in one classroom. The teacher transitions from one language to the other along with her or his students. Alternatively, Side-by-Side programs have two or more classrooms for each grade, where one teacher teaches in the partner language and the other teacher teaches in English. The students and teachers change classrooms according to an explicit schedule, whether daily or weekly. Finally, at some schools, two or more teachers may team teach in the same classroom, with each teacher using one language and a combination of whole group, small group, and independent activities facilitated by the teachers.

The Effects of Dual Language Immersion on Student Outcomes

Dual language programs promote positive academic and social outcomes for all students and particularly for English language learners (August & Hakuta 1997; Genesee, Lindholm-Leary, Saunders, & Christian, 2006; Krashen & McField, 2005; Rolstad, Mahoney, & Glass 2005; Thomas & Collier, 2004). Much of the progress of dual language programs is informed by Cummins' (1979) developmental interdependence theory which posits that for students entering school with a home language (L1) that is different from the language of schooling (L2), their academic attainment is determined by a correlation between L1 and L2 competence and socio-cultural factors pertaining to the school and community. Cummins theorized that if L1 Spanish-speaking students enter an English-only L2 school environment at a young age with only rudimentary cognitive linguistic structures, their academic attainment will be limited since they lack a strong L1 base to build on and their development of English L2 will not keep pace with native English-speaking peers. Genesse et al. (2006) refer to L1 and L2 development as drawing from a "common underlying reservoir of literacy abilities" (p. 77). The most successful programs fill this reservoir by building proficiencies in both L1 and L2. In addition to language background, students' culture must be taken into account in designing a successful dual language program. In order to support student success, Cummins' (1979, p. 240) states

> […]the school program must be geared to the needs of individual children if they are to attain an additive form of bilingualism involving fluent literacy skills in L1 and L2. If the process of instruction is to be meaningful it must reflect the child's cultural experiences and build upon his competencies.

This concept is consistent with “funds of knowledge” proposed by Moll, Amanti, Neff, and González (1992) and Gonzalez, Moll, and Amanti (2005), in which activities that are found in out-of-school settings can be used as resources to support student learning. The utility of these resources can provide authentic learning opportunities established through social contexts that facilitate the transfer of skills and knowledge.

According to Lindholm-Leary and Borsato (2001), high school students who participated in two-way immersion (TWI) programs, from elementary through high school, developed high levels of academic competence and motivation; ambitions to go to college; knowledge about how to apply to and get into college; and pride in bilingualism. In addition, students were highly satisfied with their education in the TWI programs and developed a sense of resiliency. Upon further examination, almost half of the TWI Hispanic Spanish speakers were more likely than the comparison group to make plans to go to college immediately following high school, and they were more likely to know what they need to get accepted into college (e.g., take higher-level mathematics courses). As a result, there was a significant difference in students’ enrollment in mathematics courses between the two-way group and the comparison group, which consisted of multivariate-matched students of similar demographic and academic backgrounds who attended schools without a bilingual program. Nearly half (47%) of the comparison-group enrolled in basic mathematics compared to only 3% of the two-way group. Thus, knowledge of a second language, if properly maintained throughout the school years, will be a valuable asset to students in their post-graduation endeavors (Shneyderman & Abella, 2009).

When put together well, dual language programs can have a profound impact on student outcomes. Clarkson (2007) writes that “the evidence that bilingual young people, relative to monolingual controls, show greater cognitive flexibility, creativity, divergent thought and improved problem-solving abilities, is very persuasive” (pp. 192-93). One effect of these cognitive advantages is increased academic achievement, including in mathematics and science. Several studies with students from different linguistic groups have noted improved mathematics achievement for bilingual students (Clarkson, 1992, 2007; Cobb, Vega, & Kronauge, 2006; Dawe, 1983; Gomez, Freeman, & Freeman, 2005). With respect to science, Lee (2005) argues that “desired science outcomes with ELLs include becoming bicultural, bilingual, and biliterate with regard to their home language and culture, on the one hand, and the language and culture of Western science, on the other” (p. 497).

Looking at research in mathematics and science education, learning environments that support deep learning must engage and support students in inquiry, discovery, reasoning, sense making, communication, and reflection (Marx et al., 2004; Minner, Levy, & Century, 2010; National Council of Teachers of Mathematics, 1999; National Research Council, 2000, 2007; Tarr et al., 2008). This is well-aligned with the tenets of dual language education that emphasize students’ active engagement in the learning process. Thus the improved mathematics and science achievement noted among dual language students is understandable.

Additionally, a review of literature by Marsh and Hill (2009) found extensive evidence that bilingualism (referred to as multilingualism) promotes a wide range of abilities associated with creative thinking summarized across four hypotheses supported by research:

- Multilingualism broadens access to information
- Multilingualism offers alternative ways of organising [*sic*] thought
- Multilingualism offers alternative ways of perceiving the surrounding world
- Learning a new language increases the potential for creative thought. (p. 2)

Given the emphasis on inquiry, problem solving, and communication found in new college and career ready standards, such as the *Common Core State Standards for Mathematics* and the *Next Generation Science Standards*, it is believed the cognitive benefits of the DLI approach will provide strong support for students' engagement with challenging science and mathematics learning.

In an effort to bring awareness to DLI in mathematics and science, a longitudinal study, by Ramirez, Yuen, and Ramey (1991), looked at language minority students in Spanish bilingual education programs in U.S. structured immersion English and late-exit transitional bilingual education programs. Major goals of these two U.S. based programs are to develop bilingualism by having bilingual instructors and subject matter is taught thru L2. The DLI groups had greater rates of growth than the general population (those not in DLI classrooms but from similar SES/linguistic backgrounds) in mathematics, English, and reading and that providing substantial instruction in their L1 did not impede developing language or reading skills in English. However, Shneyderman and Abella (2009) found that students in a program model that offered Spanish instruction in language arts and one content area (science or history) performed better in reading comprehension than students in a program model that offered *only* Spanish language arts instruction. Students who participated in the program also exhibited achievement levels in reading and mathematics that were the same or higher than those of demographically and academically similar students not in the program. Furthermore, the *average annual learning rates* in both academic disciplines (mathematics and language arts) were similar for program and comparison students.

Intervention: Dual Language Immersion Program at an Elementary School

Pie Elementary School (pseudonym) is a public elementary school located in Western U.S. Pie is one of the 24 elementary schools located in an urban school district. In the 2013-2014 academic year, 790 students were enrolled in Pie Elementary. Students identify mostly as Hispanic; Asian; and White, non-Hispanic. About 55% of the Pie Elementary School students have "limited English proficiency," and about 67% have subsided lunch.

The Dual Language Immersion (DLI) Program began at Pie Elementary during the 2006-2007 school year with students in Kindergarten and 1st grade. The first group of graduating students entered the DLI program at a middle school in a neighboring school district in fall 2014. The dual language immersion program at Pie Elementary develops bilingualism and biliteracy in English and a second language by integrating English Language Learners (ELLs) with English speakers (proficient in English). In particular, the DLI program at Pie has the following goals: 1) To develop language proficiency in English and Spanish for native English speakers and native Spanish speakers, 2) to ensure academic excellence as outlined in the district's core curriculum by increasing scholastic achievement in two languages, 3) to cultivate an understanding and appreciation of diverse cultures through the curriculum, and 4) to empower parents to become active participants in their children's education.

The DLI program at Pie Elementary has the following characteristics: 1) Students in each classroom have one teacher, 2) each teacher observes the language of instruction, and 3) the curriculum is based on California Content standards for grade level competencies in all subjects. The school used to have a 50:50 model. The school began a transition to the 90:10 model starting the 2014-2015 academic year as follows: Kindergarten, 90:10; Grade 1, 80:20; and Grades 2-6, 50:50 based by the subject. In phase 2 (2015-2016 academic year), the school will implement the following changes: Grade K, 90:10; Grade 1, 80-20; Grade 2: 70:30; Grade 3, 60:40; and Grade 4-6, 50:50 within the same day and based by the subject.

Pie DI teachers did not receive any formal training beyond earning bilingual authorization along with their initial credential to implement DLI. Their exposure to DLI techniques was based on mutual support and attendance of conference workshops.

Method

Research Design

To examine the achievement of the students affiliated with the dual language program in the areas of science and mathematics, we employ a host of statistical comparative analyses. The methods described in this section, whether borrowed from the existing statistical toolboxes or originally devised for the purpose of addressing the goals of our analyses, are implemented so that they would facilitate a better understanding of achievement, when it is predominantly perceived as individual-based scores in a standardized testing format. As such, these methods may need to be adjusted when the parameters factored in the definition of achievement are altered or revised.

We note, a priori, that the DLI program was implemented in a single school (Pie Elementary), while we had access to the demographic, socio-economic, and achievement scores of 23 other schools in the district. Largely, this would create an imbalance design in the study, as it leads to a significantly higher proportion of subjects in the comparison group with potentially varying set of benchmark characteristics. The homogeneity of the achievement-related predictors within most of the schools in the treatment group, coupled with a comparably small heterogeneity between them, would motivate the idea of developing a selection process for schools through defining a measure of closeness between Pie and other schools in the district. This approach will result in selecting a considerably smaller number of schools in the control group whose common characteristics with Pie will allow for the interpretability of our comparative statistical analyses.

Sample Selection

To achieve this goal, we begin by defining a weighted sum (*W*) of the proportions of those subjects within each school who were categorized as being enrolled in the free lunch program (*D*), Latino (*L*), male (*M*), enrolled in special education classes (*S*), considered either as English only or initially fluent in English proficiency (*E1*), or reclassified as English proficient (*E2*). That is, per school (Pie or otherwise), we write a weighted sum for school *j (j=1,…, 24)* as:

$$W_j = w_1 D_j + w_2 L_j + w_3 M_j + w_4 S_j + w_5 E_{1j} + w_6 E_{2j} \quad (1)$$

The weighted sum in (1) will make possible a selection process via defining a metric of closeness C between schools *j* and *k* through the calculation of

$$C_{jk} = | W_j - W_k | \; (2)$$

A plausible choice for the *w*'s in (1) is equal weights with the restriction $\sum_{i=1}^{6} w_i = 1$. This would be equivalent of putting a non-informative prior distribution on the weights of the mixture in (1). Also, in general, there will be 276 multiple comparisons in (2). Nevertheless, once we fix the index for Pie Elementary, we are left with only 23 comparisons (or distances), as in the relation (3) below:

$$C_{Pie,k} = | W_{Pie} - W_k | \; (3)$$

Therefore, schools for which $C_{Pie,k}$ is close to 0 will be formidable candidates to be considered in the subsequent comparative analyses. It is worth noticing that this approach is somewhat similar to implementing a clustering algorithm using a simple Euclidean distance with the extra benefit that we can additionally tag a level of significance (or probability) to *C*, so that the process of selecting schools similar to Pie is of some statistical value, and is not merely due to chance.

To calculate a p-value for $C_{Pie,k}$, we propose a permutation-based algorithm as follows: we treat the problem of permuting the counts of the categorical variables involved in (1), as one of permuting the contingency table resulting from cross-classifying the variable "school", having two categories: Pie and the other school indexed as *k*; against the binary categorical variables *D, L, M, S,* E_1 and E_2. Thus, if we denote the marginal sums of the categorical variable "school" as n_{1+}, and n_{2+} (for Pie and the school *k*), we can proceed by permuting the subjects in the associated table so that n_{1+} subjects are randomly redistributed among the first category of the variable of interest (for example Latino), and n_{2+} subjects are randomly redistributed among the second category of the same variable (Other Ethnicities). Continuing the permutations in this fashion, per iteration of the algorithm, we can update a value for the measure of closeness in (3). This mechanism will generate a large number of $C^{b}_{Pie,k}$, where the super-index *b* would represent the *b*-th iteration of the procedure, for *b=1,…, B.* Finally, if the problem is formulated through a hypothesis test with $H_0: C_{Pie,k} = 0$, we can subsequently derive an empirical p-value as

$$p = (\#C^{b}_{Pie,k} > C_{Pie,k})/B. \quad (4)$$

In this context, we tend to select those schools whose *p* is relatively large, so that there is little to no evidence in favor of rejecting the null hypothesis.

Variables

To develop a comparative statistical analysis of mathematics and science achievement of the students enrolled in the DLI program (treatment group) versus the others (control group), we consider a series of demographic, and socio-economic predictors, namely gender, whether a student was enrolled in the free/reduced lunch program, whether the student was self-identified as a Latino, student's English proficiency, coupled with student's performances in mathematics and science standardized examinations.

Analysis

After the selection of those schools that share common characteristics with Pie, we conduct a series of exploratory analyses, followed by building two types of models: 1) a multivariate regression model with the response variable defined as the mathematics standardized scores in the 2011, 2012, and 2013, and the predictors consisting of "gender", "ethnicity", whether the subject is registered for the "free-lunch program", "English proficiency", and whether the subject is in the "special education" program; 2) a multi-way nonparametric analysis of variance on the same set of variables included in the above model, coupled with multiple-comparison tests on the ranked data, in order to identify significant differences of the "mathematics achievement" between the treatment and control schools. We apply the same statistical techniques on the "science achievement" standardized scores with a major difference that since science standardized scores were only available for the year 2013, we consider a multiple regression model for this group.

Results

At Pie Elementary, 54% of students were enrolled in the DLI program (46% in the English-only program). Moreover, 42% of the students at Pie were in the 5th grade (58% of the 6th graders). Noticeably, 57% of students in the study's sample were female, from whom 59% were in the DLI program. In contrast, among the male students (43% of the school's framework), only 47% were enrolled in the DLI program. This may partly suggest that the parents of the female students were more open to their child's participation in the dual-language science and mathematics program.

The permutation analysis for the mathematics achievement data, spanning the years 2011- 2013, resulted in the identification of three elementary schools, Roo, Gui, and Sun (pseudonyms), as the "closest" schools to Pie. Figure 1 demonstrates the result of the permutation-based analysis. In that figure, the vertical line is the observed measure of closeness, obtained through relationship (3), and the histogram is summarizing 10,000 simulated values for $C_{Pie,}^{b}$. For example, in the right panel of Figure 1, per equation (4), the significantly large area on the right hand side of the vertical red line (observed measure of closeness) results in a large p-value.

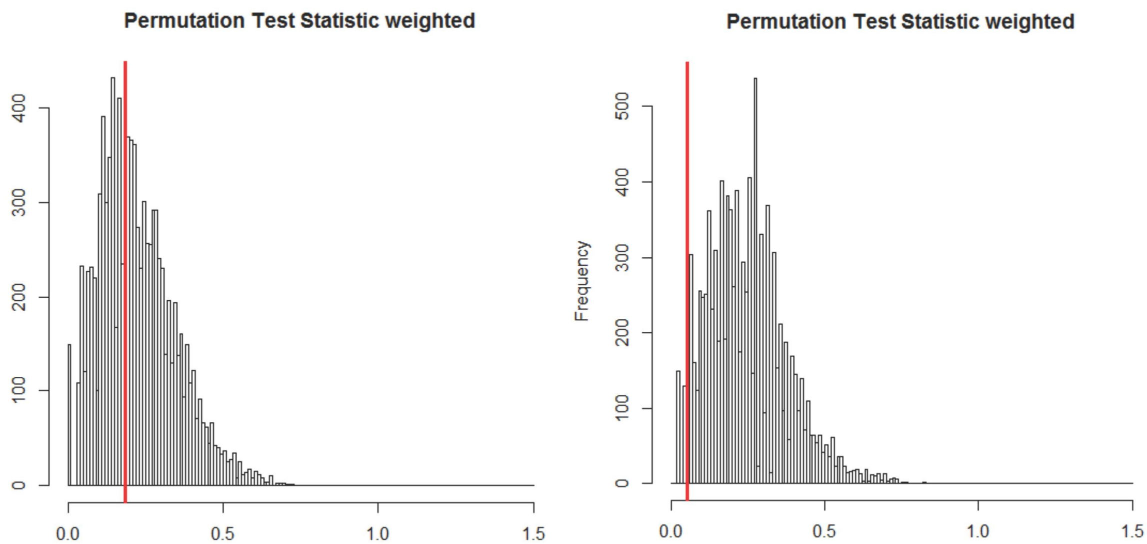

Figure 1. The results of the permutation-based analysis of closeness for the math grades in schools Gui (left) and Roo (right).

Science achivement data were only available for 2013, the year when the science DLI program began its implementation. The permutation analysis of closeness, identified four comparable schools to Pie: Roo, Gui, Jua, and Gau (pseudonyms) (Figure 2).

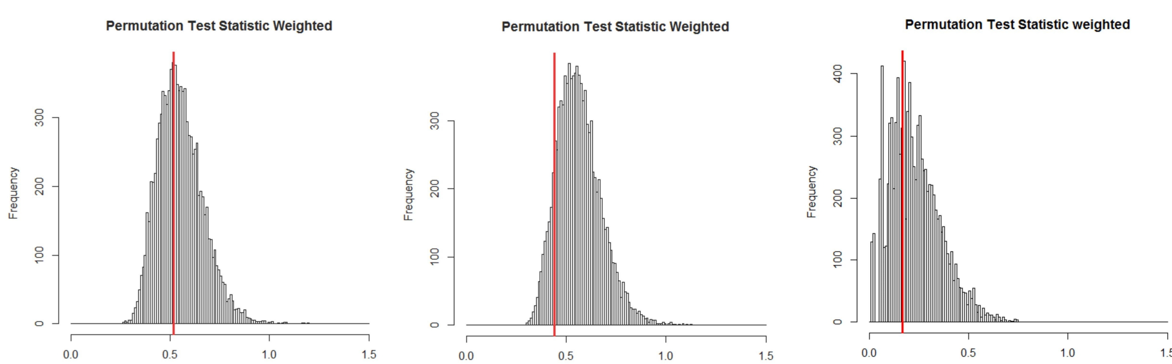

Figure 2. The results of permutation analysis of closeness for the science grades in schools Gau (left), Roo (middle), and Sun (right) .

The multivariate regression analysis, along with the nonparametric analysis of variance (ANOVA), and its post-hoc ranked-based Tukey's multiple comparison, revealed that while the mathematics scores of Pie in the three consecutive years of study (2011-2012-2013) were not significantly different than the ones at Roo, Pie demonstrated significantly higher mathematics scores than Gui (<0.06), and Sun (<0.01) for 2013, and Gui (<0.01) for 2012. This is particularly significant since, in 2011 (the first year of the DLI implementation at the district), no significant differences between Pie and its comparable schools were observed. Partly, this may be interpreted as how the DLI program began to show effectiveness only after a year of its implementation.

Table 1.

Pairwise comparisons for the Math Scaled Scores (2011-2013)

Year	Schools in Pairwise Comparison	P-value
2011	Pie - Gui	0.49
2011	Pie- Roo	0.33
2011	Pie - Sun	0.35
2012	Pie - Gui	**0.006**
2012	Pie- Roo	0.23
2012	Pie - Sun	0.07
2013	Pie - Gui	0.03
2013	Pie- Roo	0.18
2013	Pie - Sun	0.001

It is also interesting to note, as shown in Table 2, that in all three years of study, all control variables (ethnicity, free/reduced lunch, special Ed, and English proficiency) had significant effects on mathematics achievement scores.

Table 2

Coefficient Estimates of the Effects of Predictors on Math Scaled Scores (2011-2013)

Year	Variable	Coefficient	Standard Error	P-value
2011	Gender	16.27	5.93	0.006
2011	Ethnicity	-13.53	9.68	0.16
2011	Free Lunch	-18.65	8.17	0.022
2011	English Proficiency	36.79	18.09	0.041
2011	Special Education	-72.65	9.66	0.001
2012	Gender	11.08	5.35	0.039
2012	Ethnicity	-6.08	8.75	0.487

2012	Free Lunch	-21.54	7.36	0.003
2012	English Proficiency	49.44	16.25	0.002
2012	Special Education	-57.05	8.71	0.001
2013	Gender	10.73	5.48	0.056
2013	Ethnicity	-22.31	8.96	0.013
2013	Free Lunch	-15.12	7.54	0.045
2013	English Proficiency	36.79	16.65	0.027
2013	Special Education	-30.95	8.93	0.001

In the science category (Table 3), the DLI students at Pie performed significantly higher than Gui (<0.01) and Gau (< 0.06), yet no significant differences were observed when comparing Pie with Roo and Jua.

Table 3

Pairwise comparisons for the Science Scaled Scores in 2013

Year	Schools in Pairwise Comparison	P-value
2013	Pie - Gau	0.05
2013	Pie - Gui	0.001
2013	Pie - Jua	0.67
2013	Pie- Roo	0.481

In summary, the results indicate that after controlling for ethnicity, gender, special education eligibility, and free/reduced lunch participation, students enrolled in the DLI program demonstrated significantly higher mathematics scores than students in non-DLI schools. Similarly, students in the DLI program performed significantly higher than students in non-DLI schools in science. In the comparison between Pie-Roo schools, the results indicate that DLI students achieved as high as non-DLI students. This suggests that DLI students are keeping up academically while, at the same time, gaining the linguistic and cognitive benefits of biliteracy. Further discussion of the results are found in subsequent section.

Discussion

Cognitive Benefits Associated with Dual Language Immersion

There are cognitive benefits associated with DLI; including cognitive flexibility, creativity, and problem solving (Clarkson, 2007). Previously, it had been assumed that bilingualism had negative consequences on children's cognitive development. That is, learning two languages would be confusing to students (Bialystok, Craik, & Luk, 2012). This has been disproven by Peal and Lambert (1962), who found that bilingual children were superior on most tests requiring symbol manipulation, and by Ben-Zeev (1977), whose study showed a significant advantage for bilingual children in their ability to solve linguistic problems based on metalinguistic abilities. DLI and its approach to bilingual education provide students with cognitive-metalinguistic abilities not only in reading and writing, but also in mathematical- and science-based problem solving, discussions, and analysis.

These results may be attributed to the physiological and anatomical differences in the cortical tissues of monolingual and bilingual individuals, specifically in the brain area responsible for language (Bialystok, Craik, & Luk, 2012). For example, in a study exploring executive functions, Foy & Mann (2014) found that bilingual five-year olds made fewer errors and had shorter reaction times in nonverbal auditory tasks than monolinguals, no differences were found between bilinguals and monolinguals on verbal auditory task. These results suggest that early bilingualism might have advantages in nonverbal auditory stimuli under conditions that require cognitive flexibility. These advantages in executive function might explain the strong epidemiologic evidence suggesting that older adults with lifelong bilingualism have a cognitive reserve which delays and/or protects against the onset of dementia (Craik, Bialystok, & Freedman, 2010).

Common Misconceptions about DLI Programs and Student Learning

Recently, dual instruction programs in elementary schools have become prevalent all over the U.S. These programs aim to provide an excellent educational experience for English Language Learners, and to foster higher degrees of academic achievement. Research studies of several DLI programs in elementary schools indicate that these programs when executed correctly have very encouraging positive outcomes at elementary and early secondary schools for both English Language Learners and English Speakers. A significant quantity of research unveils seven factors that contribute to the performance of linguistically diverse students in dual instruction programs (Lindholm-Leary, & Howard, 2008). These factors are (1) school environment; (2) curriculum and instruction; (3) program planning; (4) assessment and accountability; (5) staff quality; (6) professional involvement; and (7) family involvement. These factors are similar to those found in successful typical programs.

Educating students in a bilingual environment has not been the norm in the U.S. Many myths and misconceptions still exist in spite of dual programs growing in popularity. With new studies and an increased body of research on dual language programs and instruction, some of these misconceptions and myths are being confronted and disproven (Espinosa, 2013). Some parents of Pie elementary school students also hold misconceptions about the DLI program. The following misconceptions held either by parents or related to parents arose through anecdotal data:

1. Pie elementary must be a private school.
2. Students in the DLI classes are gifted.
3. Students in the DLI classes do not have special needs.
4. Students in the DLI classes will fall behind in core academic subjects due to the cognitive demands of learning two languages.

As research grows, we need studies that dispel these misconceptions. We are eager to identify follow up studies of those students who participated in a DLI program at the elementary school and/or in the junior high school. Yes, results from DLI programs are encouraging in elementary grades but what happens to those students after time?

First, DLI offers promising results regarding (1) language proficiency, (2) reading and writing, (3) academic achievement—reading and math, and (4) attitudes towards school. Lindholm-Leary and Howard (2008) provide research findings about students' academic achievement, and language development and mathematics achievement of students in DLI programs at late elementary or secondary levels. Overall, they found that (1) both native Spanish speakers, and native English speakers make significant progress in both languages, (2) both groups normally perform at or above grade levels in both languages by middle school, and (3) they score at the same or better levels compare to mainstream peers (p. 194). Lindholm-Leary (2005) reported previously that in one high school "almost all TWBI [Two-Way Bilingual Immersion] students who took the Spanish advanced placement scored high enough to earn advanced placement credit…" (p. 2005).

Lindhom-Leary (2003) investigated the effect that participating in a dual-language program at the elementary school had on graduates' (high schoolers at the time) attitudes, proficiency, and use of Spanish. She found that students rated themselves at moderate levels of Spanish proficiency, had positive attitudes about the benefits of bilingualism and the program, and continued to use Spanish frequently. Furthermore, previously EL students were bilingual, had average scores in reading, were likely to be enrolled in Advanced Placement (AP) Spanish, and were obtaining fairly good grades in classes. She also found that Hispanic students noticed more benefits to bilingualism and the program than students who began the program as English only speakers. Lindholm-Leary (2003) concluded that maybe noticing these benefits enabled these students to stay and succeed in school. Lindholm-Leary and Borsato (2003) studied Hispanic high school students, who had been in a DLI program in elementary school. They observed that these students aim to not drop out of school, wish to continue into college, realize how important good grades are, show positive attitudes towards academics, feel that the DLI program has provided them with a better education, and perform as well as their non-DLI peers.

Again, most studies have focused on the status quo. More research is needed on long-term results. Linholm-Leary and Howard (2008) point to the need of research on assessment, model variations, developing reading and writing proficiencies in two languages and other contextual factors. To reiterate DLI is a promising program as it has been “found to be the program type with the highest long-term success [for English Language Learners], with students achieving well above grade level.” (Lindholm-Leary & Howard, 2008, p. 180).

Implications for Serving Disadvantaged Students and Success in STEM Education

As students enter the middle grades, academic content in mathematics and science becomes increasingly complex with concepts such as proportionality and increasingly demanding with respect to students’ ability to think abstractly and present logical arguments to explain and justify their reasoning. Cummins’ (2000) threshold hypothesis argues that for students with proficiency in two languages, prolonged opportunities to continue to develop academic content in a second language will better support students’ content knowledge development. A study by Bournot-Trites and Reeder (2001) of native English speaking students who had been in a 50/50 French-English bilingual program until grade 7 found that those students who continued to learn mathematics in French in grade 8 outperformed those who studied mathematics in grade 8 in English only. In making sense of this, Bournot-Trites and Reeder (2001) state

> *From a theoretical point of view, the 'threshold hypothesis' (Cummins & Swain, 1986) indicates that 'linguistic, cognitive, and academic advantages are associated with high levels of proficiency in both first and additional languages' (p. xvi). Therefore, higher intensity, defined as more time spent learning academic content in a second language, should produce higher proficiency in the second language and, as a result, higher academic achievement. As their second language proficiency improves, students should better understand new mathematical concepts taught in French. (p. 31).*

This cognitive advantage for DLI students in STEM is especially important for the primarily low income, limited English proficient Latino/a students in our study. In monolingual classrooms, students with a similar background typically enter middle school with below grade-level achievement in mathematics and science and leave middle school even worse off (Fry, 2007; National Center for Education Statistics, 2011).

Limitation of the Current Study and Suggestions for Future Research

The current study has several limitations. First, while the current research design allows for valid comparisons of differences observed between students in the treatment and comparison groups, the design of the study could be strengthen with an experimental study. In addition, data sources obtained from other methods such as classroom observations, teacher interviews, and student interviews would provide more information about how teachers’ instructional practices and student learning in the classroom have resulted in increasing student achievement on standardized tests. Second, even though findings of the current study contribute to the broader knowledge about the effects of dual language immersion program in science and mathematics, we caution the reader in generalizing the results as they as drawn from a specific intervention focusing on 4th, 5th, and 6th grade students. Given the relatively small sample size, students in our sample may be different from students in the general population. Third, DLI programs take time to develop and it may take even longer to observe their effects. Longitudinal data collected from this multi-year intervention will allow us to document changes in student achievement over time. Finally, we do not yet fully understand the long-term effects that this type of instruction may have on student achievement beyond elementary school. Further investigation is needed on how DLI influences the various aspects of student learning, especially in science and mathematics classrooms.

Conclusions

The results indicate that students enrolled in DLI program outperformed their counterparts on non-DLI program in both science and mathematics. More significantly, these findings highlight the potential impact of DLI programs on the teaching and learning of science and mathematics, especially for students from diverse backgrounds. More importantly, this suggests that DLI programs can have a greater impact on advancing STEM education in the U.S. The extent to which the language, as embedded in DLI programs, can enhance students' acquisition of mathematics and science content need further investigation. Consequently, educators and policy makers will need to invest in innovative programs such as DLI to not only improve student learning outcomes but also to prepare students to productively participate in an increasingly global society and workplace.

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References

Angelova, M., Gunawardena, D., & Volk, D. (2006). Peer teaching and learning: Co-constructing language in a dual language first grade. *Language and Education, 20*(3), 173-190. doi: 10.1080/09500780608668722

August, D., & Hakuta, K. (Eds.). (1997). *Improving Schooling for language-minority children: A research agenda*. Washington, D.C.: National Academy Press.

Ben-Zeev, S. (1977). The influence of bilingualism on cognitive strategy and cognitive development. *Child Development, 48*, 1009–1018. Retrieved from http://www.jstor.org/stable/1128353

Bialystok, E., Craik, F. I. M., & Luk, G. (2012). Bilingualism: consequences for mind and brain. *Trends in Cognitive Sciences, 16*(4), 240-250. doi:10.1016/j.tics.2012.03.001

Bournot-Trites, M., & Reeder, K. (2001). Interdependence revisited: Mathematics achievement in an intensified French immersion program. *Canadian Modern Language Review, 58(1),* 26-43.

Cholewa, B. & West-Olatunji, C. (2008). Exploring the relationship among cultural discontinuity, psychological distress, and academic outcomes with low-income, culturally diverse students. *Professional School Counseling, 12*, 54-61. Retrieved from http://www.jstor.org/stable/42732863

Clarkson, P. C. (1992). Language and mathematics: A comparison of bilingual and monolingual students of mathematics. *Educational Studies in Mathematics, 23*(4), 417–429. Retrieved from http://www.jstor.org/stable/3482992

Clarkson, P. C. (2007). Australian Vietnamese students learning mathematics: High ability bilinguals and their use of their languages. *Educational Studies in Mathematics, 64*, 191–215. doi: 10.1007/s10649-006-4696-5

Cobb, B., Vega, D., & Kronauge, C. (2006). Effects of an elementary dual language immersion school program on junior high achievement. *Middle Grades Research Journal, 1*, 27-47.

Collier, V.P., & Thomas, W.P. (2004). The astounding effectiveness of dual. language education for all. *NABE Journal of Research and Practice, 2*(1), 1-20.

Collier, V. P., & Thomas, W. P. (2009). *Educating English learners for a transformed world*. Albuquerque, NM: Fuente Press.

Craik, F. I. M., Bialystok, E., & Freedman, M. (2010). Delaying the onset of Alzheimer disease: Bilingualism as a form of cognitive reserve. *NEUROLOGY, 75*(19), 1726-1729. doi: 10.1212/WNL.0b013e3181fc2a1c

Cuero, K., Worthy, J., & Rodriguez-Galindo, A. (2009). Middle school choices for bilingual Latino/a youth: When the magnet school represents "status" and the neighborhood school represents "solidarity". *Urban Review: Issues and Ideas in Public Education, 41*(3), 251- 268. doi: 10.1007/s11256-008-0106-x

Cummins, J. (2000) *Language, Power and Pegagogy*. Clevedon, North Somerset: Multimlingual Matters.

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Review of Educational Research, 49*(2), 222-251. Retrieved from http://www.jstor.org/stable/1169960

Cummins, J. & Swain, M. (1986). *Bilingualism in education: Aspects of theory, research and practice*. London: Longman.

Dawe, L. (1983). Bilingualism and mathematical reasoning in English as a second language. *Educational Studies in Mathematics 14*, 325–353. Retrieved from http://www.jstor.org/stable/3482433

Delpit, L. (1995). *Other people's children: Cultural conflict in the classroom.* New York: W.W. Norton.

Espinosa, L. M. (August 2013). *PreK-3rd: Challenging common myths about young dual language learners, An update to the seminal 2008 report.* PreK-3rd, Policy to Action Brief, No. 10. Foundation for Child Development.

Fitts, S. (2006). Reconstructing the status quo: Linguistic interaction in a dual language school. *Bilingual Research Journal, 30*(2), 337-365. doi:10.1080/15235882.2006.10162880

Foy, J. G., & Mann, V. A. (2014). Bilingual children show advantages in nonverbal auditory executive function task. *International Journal of Bilingualism, 18*(6), 717-729. doi: 10.1177/1367006912472263

Fry, R. 2007. *How far behind in math and reading are English language learners?* Washington, DC: Pew Hispanic Center.

Genesee, F., Lindholm-Leary, K., Saunders, W. M., & Christian, D. (Eds.) (2006). *Educating English language learning: A synthesis of research evidence*. New York, NY: Cambridge University Press.

Gomez, L., Freeman, D., & Freeman, Y. (2005). Dual language education: A promising 50-50 model. *Bilingual Research Journal, 29*, 145-64. doi: 10.1080/15235882.2005.10162828

Howard, E. R., Christian, D., & Genesee, F. (2004). The development of bilingualism and biliteracy from grades 3 to 5: A summary of findings from the CAL/CREDE study of two-way immersion education. Santa Cruz, CA and Washington, DC: Center for Research on Education, Diversity & Excellence.

Howard, K., Lipinoga, S., Moll, L.C., & Amanti, C. (2005). Funds of knowledge: Theorizing practices in households and classrooms. *International Journal of Bilingual Education and Bilingualism, 11*(5), 627-631.

Krashen, S., & McField, G. (2005). What works? Reviewing the latest evidence on bilingual education. *Language Learner*, *1*(2), 7-10, 34.

Ladson-Billings, G. & Tate, W.F. (1995). Toward a critical race theory of education. *Teachers College Record, 97,* 47-68.

Lee, O., & Avalos, M. (2002). Promoting science instruction and assessment for English language learners. *Electronic Journal of Science Education, 7*(2). Available at http://www2.sjsu.edu/elementaryed/ejlts/

Lindholm-Leary, K. J. (2001). *Dual Language Education*. Clevedon, England: Multilingual Matters.

Lindholm-Leary, K. J (2003). *Language use and attitudes among bilingual graduates of TWI programs.* Paper presented at the Two-Way Immersion Conference, 2003. Retrieved from http://www.lindholm-leary.com/present&handout/

Lindholm-Leary, K. J. (2005). *The rich promise of two-way immersion, Two-way bilingual immersion programs go beyond language proficiency to give students academic confidence and broader cultural awareness.* Education Leadership, December 2004/January 2005, pp. 56-59.

Lindholm-Leary, K., & Block, N. (2010). Achievement in predominantly low SES/Hispanic dual language schools. *International Journal of Bilingual Education and Bilingualism, 13*(1), 43-60. doi:10.1080/13670050902777546

Lindholm-Leary, K. J., & Borsato, G. (2001). Impact of two-way bilingual elementary programs on students' attitudes toward school and college. *Center for Research on Education, Diversity & Excellence, 3*9(1), 21-31.

Lindholm-Leary, K. J., & Borsato, G. (2003). Hispanic high school students' mathematics coursework, grades and attitudes: Follow-up of immigrant English learning and fluent English speaking students in two-way bilingual programs. Paper presented at American Educational Research Association Conference, 2003. Retrieved from http://www.lindholm-leary.com/present&handout/

Lindholm-Leary, K. J., & Howard, E. R. (2008). Language development and academic achievement in two-way immersion programs. In T. W. Fortune and D. J. Tedick (Eds.) (2008). *Pathways to multilingualism: Evolving perspectives on immersion education* (pp. 177-200). Clevedon, UK: Multilingual Matters.

Marsh, D., & Hill, R. (2009). *Study on the contribution of multilingualism to creativity: Compendium part one*. Brussels: European Commission. Retrieved from http://eacea.ec.europa.eu/llp/studies/study_on_the_contribution_of_multilingualism_to_creativity_en.php

Marx, R.W., Blumenfeld, P.C., Krajcik, J.S., Fishman, B., Soloway, E., Geier, R., & Revital, T.T. (2004). Inquiry-based science in the middle grades: Assessment

of learning in urban systemic reform. *Journal of Research in Science Teaching, 41*(10), 1063-80.
doi: 10.1002/tea.20039

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474-496. doi: 10.1002/tea.20347

Moll, L., Amanti, C., Neff, D., & González, N. (1992). Funds of knowledge for Teaching: A qualitative approach to developing strategic connections between homes and classrooms. *Theory into Practice, 31*(2), 132-141.

National Center for Education Statistics (2011). The Nation's Report Card: Science 2009 (NCES 2011–451). Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Council for Teachers of Mathematics. (1999). *Principles and standards for school mathematics*. Reston, VA: Author.

National Research Council. (2000). *How people learn: Brain, mind, experience, and school*. J. A. Bransford, A. L. Brown, & Cocking, R. R., Eds. Washington, D.C.: National Academies Press.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8.* R.A. Duschl, H.A. Schweingruber, & A.W. Schouse, Eds. Washington, D.C.: National Academies Press.

National Science Foundation (2008). *Math and Science Partnership Program: Strengthening America by advancing academic achievement in mathematics and science*. Arlington, VA: Author.

Oakes, J. (1990). Opportunities, achievement and choice: Women and minority students in science and mathematics. In C.B. Cazden, (Ed.), *Review of Research In Education, 16,* 153-222.

Oakes, J., Joseph, R., & Muir, K. (2004). Access and achievement in mathematics and science: Inequalities that endure and change. In J. A. Banks & C. A. M. Banks (Eds.), *Handbook of Research on Multicultural Education* (2nd Ed.) (pp. 69-90). San Francisco: Jossey-Bass.

Peal, E. & Lambert, W. (1962). The relation of bilingualism to intelligence*. Psychological Monographs: General and Applied, 76*(27), 1–23. doi: 10.1037/h0093840

President's Council of Advisors on Science and Technology (PCAST). (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and* *math (STEM) for America's future*. Washington, D.C.: White House Office of Science and Technology Policy (OSTP).

Ramirez, J. D., Yuen, S., Ramey, D., & Pasta, D. (1991). Longitudinal study of structured English immersion strategy, early-exit and late-exit bilingual education programs for language-minority children (Final Report, Vols. 1 & 2). San Mateo, CA: Aguirre International. (ED 330 216)

Rolstad, K., Mahoney, K., & Glass, G.V. (2005). The big picture: A meta-analysis of program effectiveness research on English language learners. *Educational Policy, 19*(4), 572-594. doi: 10.1177/0895904805278067

Rubinstein-Avila, E. (2002). Problematizing the "dual" in a dual-immersion program: A portrait. *Linguistics and Education, 13*(1), 65-87. doi:10.1016/S0898-5898(01)00064-X

Shneyderman, A., & Abella, R. (2009). The effects of the extended foreign language programs on Spanish-language proficiency and academic achievement in English. *Bilingual Research Journal, 32*(3), 241-259. doi:10.1080/15235880903372829

Tarr, J. E., Reys, R. E., Reys, B. J., Chavez, O., Shih, J., & Osterlind, S. J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education, 39*, 247-80. Retrieved from http://www.jstor.org/stable/30034970

The Center for Applied Linguistics (2011, March 31). *Glossary of terms related to dual language/TWI in the United States*. Retrieved from http://www.cal.org/twi/glossary.htm

The Nation's Report Card. (N.D.). *Mathematics*. U.S. Department of Education. Accessed Feb. 18, 2012, from http://nationsreportcard.gov/math_2009/

The Partnership for 21st Century Skills (2009). The intellectual and policy foundations of the 21st century skills framework. Retrieved from http://route21.p21.org/images/stories/epapers/skills_foundations_final.pdf

Thomas, W., & Collier, V. P. (2002). A national study of school effectiveness for language minority students' long-term academic achievement (Final report: Project 1.1). Santa Cruz: University of California, Center for Research on Education, Diversity, and Excellence.

Tochon, F. V. (2009). The key to global understanding: World languages education—why schools need to adapt. *Review of Educational Research, 79*(2), 650-81.