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Mathematics development in Spanish-speaking English language learners

Shaun Wilkinson
University of Iowa

MATHEMATICS DEVELOPMENT IN SPANISH-SPEAKING ENGLISH LANGUAGE LEARNERS

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Shaun Wilkinson

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Thesis Supervisor: Professor Stewart W. Ehly

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

Shaun Wilkinson

has been approved by the Examining Committee for
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in Psychological and Quantitative Foundations (School Psychology)
at the August 2017 graduation.

Thesis Committee: ___________________________________
Stewart Ehly, Thesis Supervisor

____
Susan Assouline

____
Lia Plakans

____
Catherine Welch

____
Charlotte Wieck

ABSTRACT

Schools are required by law to identify and support English Language Learner (ELL) students. However, ELL students across grade levels consistently score well below their English-proficient peers in math. Because of this, it is imperative that the literature on effective instruction for these students remain current. Research that is available in this area has demonstrated positive relations between early ELL math performance and several demographic and school factors, including: socioeconomic status (SES), primary language proficiency, English proficiency, high-quality computer instruction, heterogeneous achievement grouping, bilingual instruction, use of cooperative learning activities, all-day kindergarten programs (as opposed to half-day), and school settings that have access to greater resources. However, this research is both limited and dated. The current study updated this literature using a recent large-scale dataset. The results indicated that a significant gap in math performance continues to exist between ELL and English-proficient students. This gap is present at kindergarten entry and persists through the spring of kindergarten. In addition, math performance at kindergarten entry was significantly accounted for by students' Spanish proficiency and SES. Models predicting math growth over kindergarten from the instructional strategy of playing math-related games and a classroom emphasis on recognizing ordinal numbers were also significant. Contrary to previous research, the adequacy of instructional materials and student program type were not significant predictors of kindergarten math growth in this study. This research provides preliminary evidence of effective strategies for instructing ELL students, although several limitations to these findings are discussed, as are implications and future directions.

PUBLIC ABSTRACT

In the United States, educational law requires schools to identify and support English Language Learner (ELL) students. Despite this obligation, ELL students across grade levels consistently score well below their English-proficient peers in math. Because of this performance gap, it is important to identify effective methods for instructing these students. Research that is available in this area has shown that ELL students with higher socioeconomic status (SES), primary language proficiency, and English proficiency tend to do better in math. In the classroom, previous research has supported the use of high-quality computer programs, grouping ELL students with non-ELL students, bilingual instruction, and cooperative learning activities. Finally, ELL students have been shown to benefit from all-day kindergarten programs and from schools that have access to more resources. The current study updated the literature in this area by using a recent large-scale dataset to examine the math performance of Spanish-speaking ELL kindergarteners. The results of this study indicate that a significant gap in math performance continues to exist between ELL and English-proficient students. This gap is present at kindergarten entry and persists through the end of kindergarten. In addition, math performance at kindergarten entry was significantly related to students' Spanish proficiency and SES. Models predicting math growth over kindergarten from the instructional strategy of playing math-related games and a classroom emphasis on recognizing ordinal numbers were also significant. However, the adequacy of instructional materials and student program type were not significant predictors of kindergarten math growth in this study.

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CHAPTER I: INTRODUCTION

In the United States, educators are required by law to identify and support students who may be at risk for academic failure (U.S. Congress, 2015). One such group is English Language Learner (ELL) students (Freeman & Crawford, 2008). While educational research and policy has focused on the language learning of ELL students (U.S. Congress, 2015), there has been a lack of research regarding these students' mathematics development (Chang, 2008; Clarkson, 2008). This is despite the fact that ELL students represent a growing population in the US (U.S. Department of Education, 2015a) who consistently scores well below Fully English Proficient (FEP) students on measures of mathematics (Chang, 2008; Chang, 2012; Han & Bridglall, 2009; Kim & Chang, 2010; U.S. Department of Education, 2015c). The current research sought to expand the literature on ELL students' mathematics development through the analysis of a recently collected national dataset.

Background of Problem

In the United States, state and local education agencies have an obligation to identify and provide language assistance services to English Language Learners – also known as English Learners or Limited English Proficient students – hereafter referred to as ELL students (U.S. Department of Education, 2015b). Potential ELL students are typically identified through the use of an education agency-developed home language survey (HLS), which often includes questions about the students' first language, home language(s), and overall exposure to language (U.S. Department of Education, 2015b). Based on the results of the HLS, potential ELL students are then assessed using a language screening test to determine whether or not they are eligible to receive additional language assistance services. Those who are eligible are therefore considered to be ELL students (U.S. Department of Education, 2015b).

ELL students in the US represent a constantly growing and demographically changing population. According to the U.S. Department of Education's National Center for Education Statistics (2015a), the overall number of ELL students in public schools in the US, as well as the percentage of all students identified as ELL, has increased over the past several years. During the 2008-2009 school year, ELL students made up 9.7% of the U.S. public school student population. By the 2013-2014 school year (the most recent year for which data are available), the number of ELL students had increased by more than 244,000 to a total of 4.9 million students, comprising 10.1% of the public school student population. Of these students, the greatest percentage – 13.5% – were enrolled in kindergarten (U.S. Department of Education, 2015a).

Data from the National Assessment of Educational Progress (NAEP) show similar trends in terms of the increasing ELL student population. For example, the percentage of fourth grade ELL students assessed on NAEP mathematics has increased every year since 1996. In 2015, the last year for which data is available, 11% of fourth grade students assessed in mathematics were identified as ELL. This represented a statistically significant increase over the 9% assessed in 2009. Among eighth grade students in 2015, 6% were identified as ELL, a significant increase from the 5% identified in 2009. Similar increases were reported for the NAEP reading assessment as well (U.S. Department of Education, 2015c).

In addition to growing, the ELL population in the United States is constantly changing in response to world affairs (e.g., immigration waves, refugee situations) both in terms of student demographics and location in the United States. Examining the home languages of ELL students across academic years provides one method of illustrating the shifting demographics of this population. Among ELL students during the 2013-2014 school year, the top five home languages spoken were Spanish, Castilian (76.5% of ELL students), Arabic (2.2%), Chinese (2.2%), English (1.9%), and Vietnamese (1.8%). It is noted that English may be reported as a home language for ELL students living in multilingual households or adopted into English-speaking households (U.S. Department of Education, 2015a). In comparison, during the 2008-2009 academic year, the top five most spoken home languages were Spanish, Castilian (77.2%), Vietnamese (2.0%), English (1.8%), Chinese (1.6%), and Arabic (1.4%). While the languages themselves have remained the same, the proportion of Arabic, Chinese, and English speakers increased over this 5-year period, while the proportions of Spanish and Vietnamese speakers decreased. To further illustrate the diversity of this student population, other less commonly spoken home languages among ELL students include: Hmong, Haitian/Haitian Creole, Somali, Russian, Korean, Tagalog, Urdu, French, Portuguese, Japanese, Panjabi/Punjabi, Bengali, Nepali, Burmese, and Hindi, among many others (U.S. Department of Education, 2015a).

In addition to students' home language, between the 2008-2009 and 2013-2014 school years the proportions of ELL students from various racial and ethnic backgrounds also shifted. While the number of ELL students from White, Black, Hispanic, Asian, and multi-racial backgrounds increased over this period, the number of Pacific Islander and American Indian/Alaskan Native students identified as ELL declined (U.S. Department of Education, 2014). Although the data are dated, Capps et al. (2005), using the results of the 2000 U.S. Census, found that 68% of ELL students between preschool and fifth grade were from low-income families, and 48% of these students had parents without high school degrees. Cosentino de Cohen and Clewell (2007) noted that much of this poverty is concentrated among Hispanic ELL students in urban areas, although it is unclear how poverty and parental education differ among different groups of ELL students.

Where ELL populations in the US are located has also changed over time, but enrollments tend to be large in certain southwestern states (e.g., California, Nevada, New Mexico, and Texas). During the 2013-14 school year, the states with the greatest percentage of ELL students included California (22.7% of all students were identified as ELL), Nevada (15.5%), Texas (15.5%), New Mexico (15.3%), Colorado (12.2%), Alaska (11.4%), and the District of Columbia (10.5%). This marked a shift from the 2008-09 school year, when the states with the greatest percentages of ELL students included: California (24.3%), Nevada (17.6%), New Mexico (17%), Texas (15.2%), Arizona (12.1%), Oregon (11.2%), Colorado (10.9%), and Hawaii (10.3%). In the span of five academic years, Hawaii, Oregon, and Arizona each dropped below 10% ELL enrollment, while Alaska and the District of Columbia both rose above that mark (U.S. Department of Education, 2015a). Finally, ELL students tend to be concentrated in large, urban schools and classrooms with high overall proportions of ELL students. These "high-ELL" schools tend to have higher incidences of poverty and have more diverse, but often less qualified and less experienced teachers (Cosentino de Cohen & Clewell, 2007). High-ELL schools are also more likely to offer Title I services, student and parent support programs, native language instruction, and to have teachers with ESL/bilingual certification (Cosentino de Cohen & Clewell, 2007).

As mentioned above, schools are required by law to identify and support students who may be at risk for academic failure (U.S. Congress, 2015). Despite this responsibility, academic data suggests that the needs of ELL students in the area of mathematics are not being met (Chang, 2008; Chang, 2012; Han & Bridglall, 2009; Kim & Chang, 2010; U.S. Department of Education, 2015c). Specifically, ELL students as a whole start kindergarten with significantly lower mathematics performance than their Fully English Proficient (FEP) peers (Chang, 2012;

Han & Bridglall, 2009; Kim & Chang, 2010). There is evidence that this gap persists or even grows larger between kindergarten and fifth grade (Chang, 2012; Kim & Chang, 2010). These findings are particularly important, as mathematics skills have been found to be among "…the most powerful predictors of later learning" (Duncan et al., 2007, p. 1443).

Researchers have investigated how this achievement gap is related to both individual and family factors, as well as certain instructional variables. With regard to student and family factors, there is some evidence that SES, primary language proficiency, and English proficiency are related to each other, as well as to the early mathematics performance of ELL students. Students who gain English proficiency earlier tend to do better in math (Halle, Hair, Wandner, McNamara, & Chien, 2012); students who are proficient in alphabetic languages like Spanish may be better able to gain English proficiency, which is then associated with better growth in math (Guglielmi, 2012); and ELL students from high-SES backgrounds, regardless of primary language spoken, demonstrate less of an achievement gap from their FEP peers (Krashen & Brown, 2005; Roberts & Bryant, 2011).

In addition to these factors, another important area of research is how ELL student mathematics performance is related to classroom and school factors. As Chang (2008) noted, the use of empirically-supported instructional practices is essential, particularly for ELL students who often lack educational support outside of school. While the amount of research in this area is limited (Chang, 2008; Clarkson, 2008), there is preliminary empirical support for incorporating high-quality computer programs into instruction (Kim & Chang, 2010), using heterogeneous achievement groups (Chang, Singh, & Filer, 2009), and using more cooperative and less teacher-centered activities like blackboard/overhead instruction (Chang, 2008; Valle, Waxman, Diaz, & Padrón, 2013). In addition, ELL students have been shown to perform better in schools that have more resources and services designed for ELL students (Han & Bridglall, 2009). Low-income and Hispanic ELL students also seem to benefit from all-day kindergarten settings, as opposed to half-day programs (Bingham & Hall-Kenyon, 2013; Chang, 2012). Finally, Hispanic ELL students have been shown to perform better in mathematics after attending high-quality pre-kindergarten settings that provide bilingual instruction (Burchinal, Field, López, Howes, & Pianta, 2012).

Taken together, the research cited above has provided preliminary information on which ELL students may be at an increased risk of experiencing mathematics difficulties (e.g., those with low levels of English literacy or from low-SES backgrounds), as well as which settings and strategies may be effective for instructing this population (e.g., all-day kindergarten programs, classrooms that employ cooperative learning). Despite this research, the ELL-FEP mathematics performance gap remains an unresolved issue. According to data collected by NAEP, the gap between ELL and FEP students in the fourth and eighth grades has stayed at nearly the exact same, statistically significant level for every year between 2007 and 2015 – the last year for which data are available (U.S. Department of Education, 2015c). In other words, almost no progress has been made in closing this achievement gap during the past decade.

Statement of Problem

Despite the importance of mathematics for later academic success (Duncan et al., 2007) and the responsibility of schools and school districts to identify and support those at risk of academic difficulties (U.S. Congress, 2015), little progress has been made in addressing the ELL-FEP mathematics achievement gap. Many researchers have pointed to the importance of identifying effective strategies for instructing ELL students in mathematics (Chang, 2008; Valle et al., 2013; Halle et al., 2012). However, actual research in this area is lacking (Chang, 2008;

Clarkson, 2008), perhaps due to the common belief that mathematics should be easy for ELL students (Furner, Yahya, & Duffy, 2005; Ganesh & Middleton, 2006; Hansen-Thomas & Cavagnetto, 2010; Janzen, 2008). Research that has been conducted in this area has often been based on data collected from students nearly a decade prior to publication (e.g., Chang, 2008; Chang, 2012; Chang, Choi, & Kim, 2015; Chang et al., 2009; Guglielmi, 2012; Halle et al., 2012; Han & Bridglall, 2009; Kim & Chang, 2010; Roberts & Bryant, 2011; Valle et al., 2013). Given the constantly changing demographics of the ELL student population described above, as well as changes to educational policies and practices over the past decade, there is a need for updated research regarding ELL students and mathematics.

Purpose of Current Study

The purpose of this study was to use the recently updated Early Childhood Longitudinal Study Kindergarten Class of 2010-2011 (ECLS-K:2011) dataset to better understand the mathematics performance of the largest group of ELL students in the United States: those who speak Spanish at home. Specifically, this study sought to identify which Spanish-speaking ELL students may be at risk for mathematics difficulties in kindergarten by examining the relation between initial mathematics performance and certain demographic variables (i.e., primary language proficiency and socioeconomic status). In addition, the current research evaluated which school factors (i.e., all-day vs. half-day kindergarten, school resources), instructional strategies (i.e., use of achievement groups and computers), and skill emphases (e.g., writing numbers, naming shapes) were associated with improvements in the mathematics performance of Spanish-speaking ELL kindergarteners.

Significance of Current Study

The No Child Left Behind (NCLB) Act of 2002 placed responsibility on schools and school districts to both identify and support students most at risk for school failure. An updated version of this legislation, the Every Student Succeeds Act (ESSA), includes similar provisions and was signed into law in December, 2015. The results of this study provide useful information regarding which Spanish-speaking ELL kindergarteners may be most at risk of delayed mathematics development. While these educational laws specifically address the language instruction needs of ELL students (U.S. Congress, 2015), they do not explicitly address mathematics instruction for this group. However, both laws do include an emphasis on the importance of implementing evidence-based instructional practices. The results of this study may be beneficial in this regard by identifying which instructional practices are most effective at addressing the mathematics needs of Spanish-speaking ELL kindergarteners.

Primary Research Questions

The primary research questions guiding this study were:

1) How is the mathematics performance of kindergarten Spanish-speaking ELL students related to their Spanish proficiency and socioeconomic status?
2) How are instructional strategies (e.g., use of achievement grouping, math games, worksheets) and skill emphases (e.g., writing numbers, naming shapes, sorting objects) associated with mathematics improvement among kindergarten Spanish-speaking ELL students?
3) How are school setting variables (e.g., all-day vs. half-day kindergarten, classroom resources) associated with mathematics improvement among kindergarten Spanish-speaking ELL students?

CHAPTER II: REVIEW OF THE LITERATURE

Achievement Gap in Mathematics

The performance of ELL students on early mathematics measures is consistently well behind the performance of their FEP peers (Kim & Chang, 2010). This gap is a particularly important area for research, as teachers often expect ELL students to perform well in math because it is considered a universal language (Furner et al., 2005; Ganesh and Middleton, 2006; Hansen-Thomas & Cavagnetto, 2010). However, years of national student data contradict this belief.

One source of information on the mathematics achievement gap comes from NAEP (U.S. Department of Education, 2015c). The NAEP mathematics assessment measures student performance across grade levels in the five areas of algebra; geometry; measurement; number properties and operations; and data analysis, statistics, and probability. Among fourth grade students who were identified as ELL, the national average mathematics score on this measure has remained between 217 and 219 – slightly above a “basic” level – for every year between 2007 and 2015, the most recent year for which data is available. During this time, non-ELL students’ scores have remained between 242 and 244, which is slightly below a “proficient” level. For reference, in fourth grade a score at or above 214 represents a basic understanding (i.e., mastery of some of the knowledge and skills expected for that grade), while a score at or above 249 represents proficient understanding (i.e., demonstrated mastery of all the knowledge and skills expected for the grade). To put it another way, this performance gap of approximately 25 points has persisted over the past 8 years.

Among eighth graders completing the NAEP mathematics measure, ELL students have averaged between 243 and 246 during this period, while non-ELL students have averaged between 283 and 287. This represents a consistent difference of about 40 points. For eighth graders, a score at or above 262 is considered a basic understanding, while at or above a 299 is considered proficient. In other words, in 2015, the average ELL student in fourth grade demonstrated a basic understanding of the NAEP mathematics content areas, while the average ELL student in eighth grade was categorized as having less than a basic understanding (U.S. Department of Education, 2015c).

It is important to note, however, that the NAEP mathematics measure is conducted in English. Because math tests can be linguistically demanding (Wolf & Leon, 2009), it is important to examine whether this gap in the NAEP data is due to real differences in math skills or differences in language proficiency. Ockey (2007) examined NAEP math performance and found evidence of a significant gap between ELL and FEP students. Furthermore, he examined whether language demands contributed to this gap using differential item functioning techniques. The author tentatively concluded that the math problems on this assessment did not inherently function differently for ELL and FEP students, and that properly written word problems can be used to assess ELL students in English without bias.

Another useful source of information on this achievement gap has been the Early Childhood Longitudinal Study – Kindergarten Class of 1998-99 (ECLS-K). The ECLS-K data was the first attempt at collecting longitudinal educational data for a cohort of students from kindergarten entry through eighth grade. Data collection for the ECLS-K began in the fall of 1998 with 21,399 kindergarteners. Additional data were collected from these students during the spring of kindergarten, the fall and spring of first grade, and the springs of third, fifth, and eighth grades, concluding in 2007. The student participants in this study were of diverse backgrounds (e.g., socioeconomic, geographic, race/ethnicity) and school settings (e.g., public and private, full-day and half-day kindergarten programs). Data collection also involved students' parents, teachers, and school administrators, in order to measure a wide range of variables at the child, home, classroom, school, and community levels (National Center for Educational Statistics [NCES], n.d.).

Using the ECLS-K data, Chang (2008) found that ELL students across four racial/ethnic groups (Asian, Black, Hispanic, and White) performed significantly lower in mathematics than their FEP peers. From kindergarten to fifth grade, this initial gap widened for Hispanic and Asian ELL students. For White ELL students, the math achievement gap narrowed over this time, but did not close. For Black ELL students, interpretations were deferred due to the low sample size of this group ($n = 26$). Using the ECLS-K data again in 2009, but this time not broken down by race/ethnicity, Chang et al. found that ELL students in kindergarten, first, and fifth grades performed significantly lower in mathematics than their FEP peers. ELL students also performed lower in third grade, but this difference was not significant. Additional research using this dataset has continued to demonstrate a significant initial gap in mathematics performance at kindergarten entry (Chang, 2012; Han & Bridglall, 2009; Kim & Chang, 2010;) that persists or grows larger between kindergarten and fifth grade (Chang, 2012; Kim & Chang, 2010). One limitation of the ECLS-K data is that the mathematics assessment was again conducted in English. It is unclear how linguistic demands on the ECLS-K mathematics assessment may have impacted ELL student performance in this dataset.

Based on the information provided above, there is a well-documented achievement gap between ELL and FEP students that has persisted for the past 15 years. It is important to examine this gap in order to understand the various factors that may be contributing to it, as well as how it may be addressed in the classroom and school.

Research on ELL Math Performance

Student and Family Factors

English language proficiency. Several student and family factors have been found to be associated with ELL performance in mathematics. One such factor is students' English literacy proficiency. While teachers often believe that mathematics is a universal language that should be easy for ELL students (Furner et al., 2005; Ganesh and Middleton, 2006; Hansen-Thomas & Cavagnetto, 2010), such beliefs ignore both ELL students' needs and the linguistic complexity of mathematics (Hansen-Thomas & Cavagnetto, 2010). According to Lager (2006), in order to be successful in mathematics, students must have both everyday language skills, as well as specialized mathematical language skills. Unfortunately, many ELL students lag behind their FEP peers in these areas, and therefore cannot fully access the content of their mathematics lessons (Lager, 2006). Halle et al. (2012), examined the relation between literacy and mathematics performance using the ECLS-K dataset described above. These authors broke the entire ECLS-K dataset into 2,670 ELL students and 19,890 FEP students based on parents' reported language spoken at home (i.e., students whose parents reported a language other than English spoken primarily at home were categorized as ELL). These authors found that ELL students who were proficient in oral English when they entered kindergarten did not demonstrate an initial achievement gap in math with their FEP peers, and had comparable growth rates in both reading and math until eighth grade. The ELL students who were not proficient in oral English by the spring of first grade, however, did have an initial performance gap in both reading and math that persisted through eighth grade. These results were obtained after controlling for age at school entry, disability status, parent education, and family income. It is important to note, however, that these authors defined ELL students as those who spoke a language other than

English at home, and therefore some students proficient in English were categorized as ELL for the purposes of this study (Halle et al., 2012). Related to English proficiency is the finding that ELL students may perform worse on certain mathematics measures because of construct-irrelevant variance due to the linguistic complexity of the measure's items (Martiniello, 2009). In other words, it is likely that part of the mathematics achievement gap between ELL and FEP students is due to the linguistic demands of the test itself, and is not actually representative of a difference in mathematics ability. While Ockey (2007) found minimal impact of language on ELL math performance in the NAEP data, it is unclear what influence it may have had in the original ECLS-K dataset.

Primary language proficiency. The relation between English proficiency and mathematics performance may also be influenced by ELL students' primary language proficiency. Guglielmi (2012) examined this relation using another longitudinal dataset of 27,000 individuals who were first sampled in eighth grade in 1988 and were then followed for 12 years (only 4 of which were considered schooling years). Guglielmi (2012) identified ELL students from this dataset based on their English proficiency and their reported primary language (n = 1,390). After controlling for family and school-level variables (i.e., family income, number of grades completed outside of the US, school percentage of minority students, and teacher morale), the author found that, for Hispanic ELL students, primary language proficiency predicted the development of English proficiency, which in turn predicted growth in mathematics (Guglielmi, 2012). The authors noted that this finding did not hold for non-Hispanic ELL students, most of whom were Asian. The largest primary language group of Asian ELL students was Chinese, which the authors noted may be more difficult to transfer literacy skills to English from because of its non-alphabetic nature.

Primary language. Roberts and Bryant (2011) were also interested in the relation between home language and mathematics performance for ELL students who spoke either Spanish or an Asian language. These authors identified only English-proficient ELL students in the ECLS-K data – using a similar definition of ELL as Halle et al. (2012) described above – in order to examine if the language itself (i.e., Spanish or an Asian-language) explained mathematics performance. They also examined how socioeconomic status (SES) influenced mathematics performance both within and across language groups. The results demonstrated that students' SES explained more of the variance in mathematics achievement than did primary language (Roberts & Bryant, 2011). This finding indicated that whether students spoke Spanish or an Asian language did not seem to impact their mathematics performance as much as their SES did.

Socioeconomic status. Krashen and Brown (2005) also examined the impact of SES on mathematics performance. In a review of several sets of data, these authors found that high-SES ELL students performed just as well as, and sometimes better than, low-SES FEP students in mathematics and reading. They also noted the seeming contradiction in ELL students performing better than FEP students on a test of reading, which ought to call into question how students were being identified for those categories. The authors attributed the performance of high-SES ELL students to a number of factors, including: prior opportunities for appropriate education in their primary language, caregivers who are more highly educated and equipped to help with schoolwork, and greater access to books and print. It is also likely that high-SES ELL students attend schools with more physical resources, which has been associated with faster learning rates in mathematics (Han & Bridglall, 2009).

Summary. In summary, there is some evidence that SES, primary language proficiency, and English proficiency are related to each other, as well as to the early mathematics performance of ELL students. Students who gain English proficiency earlier tend to do better in math (Halle et al., 2012); students who are proficient in alphabetic languages like Spanish may be better able to gain English proficiency, which is then associated with better growth in math (Guglielmi, 2012); and ELL students from high-SES backgrounds demonstrate less of an achievement gap from their FEP peers (Krashen & Brown, 2005; Roberts & Bryant, 2011).

Classroom and School Factors

In addition to the research available on individual and family factors, some research has also been conducted on how classroom and school factors are related to the mathematics performance of ELL students.

Instructional strategies. Several authors have offered input as to how the mathematics needs of ELL students may be best addressed in the classroom. Research in this area has supported the use of computers (Freeman & Crawford, 2008; Furner et al., 2005; Ganesh & Middleton, 2006; Kim & Chang, 2010), achievement grouping (Chang, 2008; Chang et al., 2009; Furner et al., 2005), and other strategies like using manipulatives, drawings, and real-world examples (Furner et al., 2005; Janzen, 2008; Valle et al., 2013).

Computerized instruction. One method for making mathematics lessons more accessible to ELL students, and thus improving their development in this area, is through the use of computerized mathematics instruction or intervention software (Furner et al., 2005). Such programs have many potential benefits as a replacement or supplement to traditional lecture-based math instruction. Specifically, their interactive nature may help build student motivation while providing a non-judgmental and safe place for students to practice their skills (Ganesh &

Middleton, 2006). Computerized mathematics software may also allow students to learn at a pace appropriate for their linguistic and mathematic proficiency, can provide re-teaching on demand, and may be programmed to scaffold ELL student learning through built-in language supports (Freeman & Crawford, 2008; Ganesh & Middleton, 2006; Kim & Chang, 2010). Such language supports are important for allowing ELL students to fully access the material, and may include the use of simple and consistent language, explicit math vocabulary instruction, frequent repetition, and word banks (Bresser, Melanese, & Sphar, 2009; Furner et al., 2005; Hansen-Thomas & Cavagnetto, 2010; Janzen, 2008; Lager, 2006).

However, it is important to note that simply providing computers to ELL students is not likely to benefit their mathematics development. Based on 2 years of observations, semi-structured interviews, and document analysis in a single elementary school in urban Arizona, Ganesh and Middleton (2006) proposed several reasons as to why the use of computers for mathematics may fail ELL students. First, schools may not have access to the types of high-quality mathematics software that are appropriate for ELL students. In order for students to effectively use computers to learn mathematics, the language requirements of the software must be appropriate for their level of English proficiency. Additionally, even when appropriate software is available, teachers must know how to access the software and how to build it effectively into instruction (Ganesh & Middleton, 2006).

These potential benefits of and considerations for using computers to address ELL students' mathematics needs were reiterated by Kim and Chang (2010). Using the ECLS-K dataset, these authors explored the longitudinal effects of three computer-related variables – "home computer access," "computer use for various purposes," and "computer use at school for math" (p. 287-8) – on ELL students' math achievement. Kim and Chang noted that, in general, each of these variables had previously been found to be positively associated with mathematics achievement among the overall student population. The authors found that, after controlling for the effects of an SES composite (based on parent occupation, income, and education level), gender, language status, and age, home computer use had positive effects for FEP students and negative effects for ELL students. Computer use for various purposes demonstrated positive effects for Black and Hispanic ELL students. Black, Hispanic, and Asian ELL students who used computers in school for math were found to have higher math achievement than their same ethnicity ELL status peers who did not use computers in school for math. For Hispanic and Asian ELL students who used computers in school for math, the gap in mathematics performance between them and their FEP peers was reduced over time, although this effect was only significant for the Asian ELL students. Kim and Chang (2010) concluded that parents and educators should use this information to identify ways in which computers may be used to enhance learning for ELL students. Specifically, they stated that guiding computer use towards educational activities, and using programs that support limited English skills would likely be more beneficial to math development than merely providing access to a computer at home or at school.

In summary, computers offer one potential method for addressing the mathematics needs of ELL students, and have been associated with improvements to ELL students' mathematics achievement (Kim & Chang, 2010). ELL students will likely get the most benefit from programs that are specifically designed to support their unique needs by incorporating language supports and opportunities for repetition and re-teaching (Freeman & Crawford, 2008; Ganesh & Middleton, 2006; Kim & Chang, 2010).

Achievement grouping. Another recommendation for teachers working with ELL students in mathematics has been to group students heterogeneously with their FEP peers, so that both groups may benefit from the other's knowledge and experience (Furner et al., 2005). Chang et al. (2009) examined the use of such grouping practices and its effect on the mathematics performance of ELL students using the ECLS-K data. In this study, achievement grouping was identified as the practice of placing students in small groups for instruction based on their previous academic performance and tailoring instructional tasks to their perceived achievement level (i.e., homogenous grouping). These authors found that, overall, ELL students were placed in achievement groups for math more frequently than their FEP peers at every grade level from kindergarten through fifth grade. The authors also concluded that, for both ELL and FEP students, achievement grouping negatively influenced mathematics achievement. In addition, the use of achievement grouping was associated with significantly less growth in mathematics performance longitudinally for ELL students compared to FEP students. In other words, the performance gap between these two groups grew when the use of achievement grouping was high. When explaining these results, the authors stated that when ELL students are placed in lower achievement math groups – likely because of their limited English proficiency – they may receive lower-quality instruction, lose opportunities to interact with and learn from higher achieving peers, and may experience decreased academic motivation. The results of this study supported the recommendation to use heterogeneous grouping with ELL students rather than homogenous/achievement grouping, which the authors concluded may impede educational equality (Chang et al., 2009).

Bilingual instruction. Another recommendation for improving ELL student academic performance has been to use bilingual instruction (Krashen & Brown, 2005). Bilingual education programs may be beneficial to ELL students' academic achievement by raising their self-esteem and academic self-concept, and by providing them with literacy skills in their primary language that may transfer to English (Guglielmi, 2012). In a study cited above, Guglielmi (2012) examined this proposed model and found evidence that it fit only for Hispanic ELL students. Again, the author noted that the reason this model did not fit for the Asian ELL students in the sample may have been due to the added challenge of transferring literacy skills from a non-alphabetic to an alphabetic language (Guglielmi, 2012).

Burchinal et al. (2012) also researched the efficacy of bilingual education among pre-kindergarten Hispanic ELL students (n = 357). In this study, students were identified as ELL if they did not pass an English-language screener. The quality of the students' classroom was included as another variable, and was rated by a trained observer using the Classroom Assessment Scoring System. The results of this study indicated that the reading and mathematics development of Hispanic ELL students in high quality pre-kindergarten programs benefited from increased instruction in Spanish. The authors noted that classrooms in which more Spanish instruction is used may be more culturally supportive of Hispanic ELL students, and may allow such students to develop a closer relationship with their teacher, whereas students in classrooms where Spanish is spoken less may feel more isolated (Burchinal et al., 2012).

Other instructional practices. Several other instructional practices have been recommended for teaching mathematics to ELL students, including providing culturally relevant or real-world examples; using manipulatives; incorporating drawings into exercises; and using a more cooperative, collective learning format, as opposed to the teacher-centered mathematics instruction common in American schools (Furner et al., 2005; Janzen, 2008). However, little research is available on the effectiveness of these strategies for meeting the educational needs of ELL students.

Valle et al. (2013) conducted such a study, examining the relation between several instructional strategies and the mathematics performance of Hispanic ELL students in fifth grade. These authors used a stratified random sample from the ECLS-K data, selecting 100 students from each of the following groups: White non-Hispanic non-ELL, Hispanic non-ELL, and Hispanic ELL. Some students were eliminated during this stratification process based on their school setting (private vs. public), their SES, or their parents' education level, due to a low representation of ELL students in certain strata. This study focused on four instructional formats: teacher-directed whole class, teacher-directed small group, teacher-directed individual activities, and child-selected activities. In addition, the authors examined the frequency with which teachers used specific instructional strategies, including: solving textbook or worksheet problems, solving blackboards or overheads problems, completing problems in small groups or with partners, using measuring instruments, using manipulatives, writing instructions to solve problems, discussing problems and solutions with other children, using problems that reflect real-life situations, computers-based math work, and using visual representations. The only significant finding relevant here was that Hispanic ELL students performed worse when their instruction involved an increased use of solving math problems on the blackboard or overhead projector. The authors hypothesized this finding to be due to the mentally demanding processes of watching and listening, mentally translating, and analyzing the problem, all while copying down the steps involved from a board or projector. However, the authors warned against generalizing these results further, due to the characteristics of their sample and the methodology used (Valle et al., 2013).

Chang (2008) also investigated the use of the same four instructional formats used by Valle et al. (2013): teacher-directed whole-class activity, teacher-directed small-group activity, teacher-directed individual activity, and student-selected activity. With regard to ELL students, over time Hispanic ELL students' mathematics performance developed significantly slower in classrooms that were high in teacher-directed whole-class activities, while Asian ELL students' performance developed significantly slower when the amount of teacher-directed small-group activities was high. The author cautioned teachers who work with Hispanic and Asian ELL students to monitor their use of these practices with these students, and to provide additional help for students whose needs may not be met during these activities (Chang, 2008).

School resources and organization. In addition to classroom variables, factors at the school level may also impact ELL students' mathematics performance. In particular, researchers have examined the impact of kindergarten setting (Bingham & Hall-Kenyon, 2013; Chang, 2012) and overall school programs and resources (Ganesh & Middleton, 2006; Han & Bridglall, 2009).

All-day vs. half-day kindergarten. Noting the potential benefits of all-day kindergarten programs as compared to half-day programs (e.g., the opportunity for a slower pace, more opportunities for repetition, and increased individualization), Chang (2012) examined the effect of all-day kindergarten for ELL, dual-language, and English-only students from four racial/ethnic groups (i.e., Asian, Black, Caucasian, and Hispanic) using the ECLS-K data. No significant effects of all-day vs. half-day kindergarten were found when comparing ELL students of all racial/ethnic groups across all SES backgrounds. However, among low-SES ELL students, attending an all-day kindergarten was associated with significantly higher reading and mathematics growth rates for Asian ELL students, and significantly lower math performance for Caucasian ELL students, a result the author attributes to the high variance for this latter group.

This study also found positive effects of all-day kindergarten programs for Asian, Black, and Hispanic dual-language students (i.e., defined in this study as students who primarily spoke a language other than English at home, but who were not identified as needing ELL services at school). Chang (2012) concluded that all-day kindergarten programs should be supported, particularly in areas that serve low-SES and non-English-proficient students.

Bingham and Hall-Kenyon (2013) also examined the impact of all-day and half-day kindergarten, as well as attendance, on kindergarten academic achievement. These authors used a sample of kindergarten children (n = 1,399) from a large urban school district, of which 390 were classified as ELL because their primary language spoken at home was identified as Spanish. A comparison group of 390 FEP students was randomly selected from the larger pool in order to examine whether the effect of kindergarten setting differed for these two groups. The findings of this study indicated that attending all-day kindergarten was associated with significantly better literacy and mathematics performance at the end of kindergarten for both ELL and FEP students. However, an achievement gap was still found for literacy at the end of kindergarten between ELL and FEP students who attended all-day settings. Therefore, while ELL students benefited from being in an all-day setting, they were not able to significantly close the performance gap in literacy. The difference between ELL and FEP students' mathematics scores, on the other hand, was not statistically significant. The authors concluded that the all-day kindergarten ELL students may have narrowed the performance gap with their FEP peers. Finally, for both groups of students in both types of settings, academic performance was better when school attendance was higher (Bingham & Hall-Kenyon, 2013).

School programs and resources. Finally, ELL student performance may be related to the school itself, the amount of resources it has, and the number of programs available to ELL families. Using the ECLS-K data, Han and Bridglall (2009) found that ELL students in schools with an identified ELL population were able to narrow the mathematics achievement gap by fifth grade. The authors concluded that ELL students in schools that identify themselves as having an ELL population likely have access to more resources designed to assist their specific learning needs. They stated:

> "Our analysis suggests that schools offering more Title I services (e.g., extending learning time before and/or after school for targeted children, family literacy services) and services for ESL families (e.g., translators available for parent-teacher conferences, outreach workers to assist families enrolling children) allowed ELL children to improve their math scores faster than their English-speaking peers" (p. 459).

Related to the bilingual education findings noted above, Han and Bridglall (2009) also found negative effects of having a monolingual English teacher on ELL students' mathematics growth. Finally, schools with more physical resources and with teachers who put forth more effort were associated with significantly increased growth rates in mathematics (Han & Bridglall, 2009).

Summary. Many recommendations have been made regarding best practices for instructing ELL students in mathematics. Of the practices identified above, there is preliminary empirical support for incorporating high-quality computer programs into instruction (Kim & Chang, 2010), using heterogeneous achievement groups (Chang et al., 2009), and using more cooperative and less teacher-centered activities like blackboard/overhead instruction (Chang, 2008; Valle et al., 2013). Hispanic ELL students have also been shown to perform better after attending high-quality pre-kindergarten settings that provide bilingual instruction (Burchinal et al., 2012), as well as in schools that have more resources and services designed for ELL students

(Han & Bridglall, 2009). Finally, low-income and Hispanic ELL students also seem to benefit from all-day kindergarten settings as opposed to half-day settings (Bingham & Hall-Kenyon, 2013; Chang, 2012).

Limitations of Previous Research

While the research cited above has provided some preliminary information on ELL students who may be at risk for mathematics difficulties, as well as potential strategies for addressing the mathematics achievement gap between ELL and FEP students, several limitations to this literature should be noted. First, while many researchers have acknowledged the importance of identifying instructional practices that support ELL students' mathematics development (Chang, 2008; Halle et al., 2012; Valle et al., 2013), not enough research has been conducted in this area (Chang, 2008; Clarkson, 2008). Janzen (2008) attributed this lack of research to the misguided notion that mathematics should be easy for ELL students.

Second, the research that has been completed in this area has not kept pace with the changing demographics of the ELL student population. For example, Guglielmi's 2012 study participants were in the eighth grade in 1988. In addition, the students whose data comprises the original ECLS-K dataset, on which much of research cited above is based, entered kindergarten in 1998. To further illustrate this point, take the case of Kim and Chang's (2010) research on computer use among ELL students. Given the rapid advancements in computer technology and software even within the past decade, it is likely that the results of this study – which relied on ECLS-K data collected between 1998 and 2003 – were already outdated at the time of publication.

Finally, much of the research on the mathematics performance of ELL students is based on assessments conducted in English. As noted above, ELL students may perform worse on mathematics assessments taken in English simply because of the linguistic complexity of the items (Martiniello, 2009). Although there is evidence that this did not significantly impact performance in the NAEP data (Ockey, 2007), it is unclear what impact linguistic complexity had in the original ECLS-K data. These factors all point to the need for updated research on the mathematics performance of ELL students, particularly research that limits the potential impact of linguistic demands.

Current Research Questions

While some of the predictors of mathematics performance for ELL students are not easily addressed in the classroom (e.g., SES), such predictors are important areas for research in understanding which students should be targeted for preventative services. In addition, the educational impact of classroom supports and interventions for ELL students has been identified as an important area for future research (Halle et al., 2012). With these issues in mind, in addition to the limitations of the previous research identified above, the purpose of the current study was to use the recently updated ECLS-K:2011 dataset to examine the following research questions:

1) How is the mathematics performance of kindergarten Spanish-speaking ELL students related to their Spanish proficiency and socioeconomic status?
2) How are instructional strategies (e.g., use of achievement grouping, math games, worksheets) and skill emphases (e.g., writing numbers, naming shapes, sorting objects) associated with mathematics improvement among kindergarten Spanish-speaking ELL students?

3) How are school setting variables (e.g., all-day vs. half-day kindergarten, classroom resources) associated with mathematics improvement among kindergarten Spanish-speaking ELL students?

CHAPTER III: METHODOLOGY

Data Source

As described in Chapter 2, the original ECLS-K dataset provided researchers with national data with which to study the mathematics performance of ELL students. However, a limitation of using this dataset for contemporary analyses is that the cohort of students from which the data were collected entered kindergarten in the fall of 1998. Many changes in the ELL student population have occurred since that time, as described in previous chapters. Fortunately, an updated version of this study, the Early Childhood Longitudinal Study Kindergarten Class of 2010-2011 (ECLS-K:2011), has recently been conducted. The purpose of this nation-wide data collection effort was to allow researchers to examine how individual, family, school, and community-level variables are associated with academic performance from kindergarten entry through fifth grade (NCES, n.d.).

Data collection for the ECLS-K:2011 began in the fall of 2010 with a nationally representative sample of 18,174 kindergarteners from diverse backgrounds (e.g., socioeconomic, geographic, race/ethnicity) and school settings (e.g., public and private, full-day and half-day kindergarten programs). The actual sampling process was conducted in three stages. First, the country was divided into geographic primary sampling units, from which 90 were sampled for inclusion. From these units, public (n = 1,306) and private schools (n = 283) with kindergarten programs were sampled. At each of these first two stages, probability sampling was conducted that was proportional to measures of kindergarten student population size (i.e., areas and schools with more kindergarten-aged students were more likely to be sampled). Finally, students attending these schools were sampled for voluntary participation (Tourangeau et al., 2015a).

Additional data regarding sampled students were collected during the spring and fall of 2011 and 2012, and the springs of 2013, 2014, and 2016. For most students, these data collection points corresponded to the fall and spring of kindergarten, first, and second grades, and the springs of third and fifth grades, although students who were repeating previous grades during subsequent data collection remained in the study. The data themselves were collected by trained field staff, who assessed students directly, interviewed students' parents, and obtained additional information through questionnaires completed by students' teachers, school staff, and day care providers.

Procedures

Data Preparation

The ECLS-K:2011 dataset is available in two formats: a public-use dataset and a restricted-use dataset. Both versions of the dataset are currently in the process of being released; the entire dataset is expected to be released by the fall of 2018. Currently, the public-use dataset contains kindergarten and first grade data. It is freely available and was downloaded directly from the National Center for Educational Statistics website for this study.

Participants

Participants were selected from the ECLS-K:2011 dataset based on their parent-reported primary language spoken at home and their score on a language screener at kindergarten entry. As part of the ECLS-K:2011 data collection process, most of the 18,174 kindergarten students (n = 15,784) were first administered 20-items from the Preschool Language Assessment Scale (*Pre*LAS 2000) as a preschool-level English language screener (more details on this assessment are provided in the next section). Students who answered 12 or more of the 20 items correctly or who spoke only English at home (n = 15,377) were routed to complete the mathematics assessment in English. Students who spoke Spanish at home and who answered 11 or fewer of the items correctly (n = 344) were routed to complete a translated version of the mathematics assessment. Students who spoke a language other than English or Spanish at home and who did not pass the language screener were not assessed in mathematics (n = 63). Because of this, the analyses in this study focused on the performance of Spanish-speaking ELL kindergartners as identified by those students who spoke Spanish at home and who did not pass a preschool-level English language screener. This identification procedure was similar to the one used by Guglielmi (2012).

These 344 students were enrolled in 127 schools (1 private, 126 public) and included 170 males and 172 females (sex was not ascertained for 2 individuals). Most students were identified as Hispanic through parent and school report (n = 314). For 28 students, ethnicity was not ascertained, while 2 students were identified as non-Hispanic.

When using ECLS-K:2011 data, it is recommended that sample weights be employed to compensate for the probability sampling employed in data collection, as well as to adjust for the impact of nonresponse bias (Tourangeau et al., 2015b). The publishers of the ECLS-K:2011 included several such weights in the publicly available dataset. The specific weight selected for this study was W12AC0, which adjusts for both teacher response (A) and child assessment (C) data during both the fall and spring of kindergarten (i.e., times 1 and 2, respectively). In other words, this weight adjusted for all variables under investigation in the present study. The weights themselves were adjusted to produce normalized weights, which sum to the sample size instead of the population size. This was done, as recommended by Hahs-Vaughn (2005), to address sample size sensitivity (i.e., the fact that analyses using population size are likely to be statistically significant, even if not practically significant). Demographic information for all 344

ELL students using both raw sample values and normalized weighted values is detailed below in Table 1. Normalized weights, in turn, were used to calculate design effect adjusted weights, which are described in detail later in this chapter.

Table 1.
Spanish-Speaking ELL Student Demographics

Demographics	Hispanic *n* (normalized weighted *n*)	Non-Hispanic *n* (normalized weighted *n*)	Not Available *n* (normalized weighted *n*)	Total *n* (normalized weighted *n*)
Gender				
Male	157 (157)	2 (2)	13 (13)	172 (172)
Female	157 (157)	0 (0)	13 (13)	170 (170)
Not Available	0 (0)	0 (0)	2 (2)	2 (2)
Total	314 (314)	2 (2)	28 (28)	344 (344)
Race				
White	276 (283)	1 (0)	0 (0)	277 (285)
Black	1 (2)	1 (0)	0 (0)	2 (2)
Asian	1 (2)	0 (0)	0 (0)	1 (2)
Alaskan Native or American Indian	2 (1)	0 (0)	0 (0)	2 (1)
Multi-Racial	5 (3)	0 (0)	0 (0)	5 (3)
Not Available	29 (30)	0 (0)	28 (23)	57 (53)
Total	314 (321)	2 (0)	28 (23)	344 (344)

In addition to the primary research questions, preliminary analyses were conducted to examine whether a mathematics performance gap exists in the ECLS-K:2011 dataset. The process for conducting this analysis was modelled after the procedures used by Valle et al. (2013). Specifically, a stratified random sample was extracted from the ECLS-K dataset based on race/ethnicity, socioeconomic status, parent education, and school type (i.e., public or private). First, students who were missing data related to any of these variables were removed from the possibility of further selection, as were students for whom mathematics performance data for both the fall and spring of kindergarten was unavailable. Next, again following the procedures of Valle et al. (2013), when stratifying by socioeconomic status, students in the top fourth and fifth quintiles were removed due to limited representation among Hispanic ELL students ($n = 3$). Students attending private schools and students whose parents had a graduate or professional degree were removed for this same reason (*n* of 1 and 3 among Hispanic ELL students, respectively). Finally, SPSS software was used to randomly select 100 students from each of the following racial/ethnic/linguistic groups: Hispanic (any race) ELL, Hispanic (any race) FEP, and White non-Hispanic FEP. Demographic information for this sample are detailed in Table 2. This stratification process limits generalizability, as was the case with Valle et al. (2013), because the sample used for this analysis was not nationally representative. However, the purpose of this preliminary analysis is simply to determine whether and to what degree a performance gap is present in the ECLS-K:2011 dataset.

Table 2.
Demographics of Preliminary Analysis Sample

Demographics	Hispanic ELL (any race)	Hispanic FEP (any race)	White non-Hispanic FEP
Gender			
Male	50	53	52
Female	50	47	48
Parent education			
Grade 8 or below	46	11	3
Grades 9-12	17	24	12
High school or equivalent	29	44	29
Vocational/Technical program	1	5	10
Some college	6	11	39
Bachelor degree	1	5	7
Socioeconomic status			
First quintile	87	55	26
Second quintile	12	27	38
Third quintile	1	18	36

Measures

All student data was collected by trained field staff who were certified to administer child assessments. The certification process involved interactive lectures and material review sessions, role-play practices, and written exercises. During the final stage of the certification process, trainees conducted a live assessment while being observed by a certified assessor who provided feedback and inter-rater reliability. Only trainees who met criteria during this assessment (i.e., passed 85% of the possible points) were certified to administer child assessments. The actual one-on-one child assessments typically occurred in an unoccupied classroom, meeting room, or the school library (Tourangeau et al., 2015b).

Preschool Language Assessment Scale (*Pre*LAS). In order to route participants to linguistically appropriate assessments, two tasks from the *Pre*LAS were used as a preschool-level English screening measure. According to Tourangeau et al. (2015b): "The 'Simon Says' task required children to follow simple, direct instructions given by the assessor in English. The 'Art Show' task was a picture vocabulary assessment that tested children's expressive vocabulary" (p. 2-3). Both of these tasks included 10 items, resulting in a 20-item screening measure. The overall reliability of this measure was provided as an alpha coefficient of 0.91 for the fall of kindergarten, the time when this measure was used to categorize students as ELL or FEP for the current study. The alpha coefficients for each specific task were reported as 0.85 and 0.86 for Simon Says and Art Show, respectively (Tourangeau et al., 2015b).

Spanish Early Reading Skills (SERS). Students who did not pass the *Pre*LAS (i.e., those who answered 11 items or fewer correctly out of 20) and who spoke Spanish at home completed the 31-item SERS assessment. According to the publishers, these items came from an English reading assessment that had been translated into Spanish (Tourangeau et al., 2015b). Scores on this assessment were calculated using IRT procedures, which allows for the comparison of scores across difficulty and grade levels. For IRT scaled scores, reliabilities were "…based on the variance of repeated estimates of theta for each individual child compared with total sample variance" (Tourangeau et al., 2015b, p. 3-10). Although theta scores, an estimate of ability, were not used in this study, the author noted that these reliability values apply to IRT scale scores as well. Reliability for the SERS assessment during the fall of kindergarten (i.e., the only period under investigation) was reported as 0.99.

Mathematics. Participants were also individually administered a mathematics assessment adapted specifically for this study and designed to measure conceptual knowledge, procedural knowledge, and problem solving (Tourangeau et al., 2015a). Specifically, items covered the following topics: "…number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and patterns, algebra, and functions" (Tourangeau et al., 2015a, pp. 2-6). Each assessment began with a set of 18 routing items that determined the difficulty level of future items. Although students were routed to one of three difficulty levels for the remaining items (i.e., low, medium, or high difficulty), common items were administered across all three difficulty levels for the purpose of calculating IRT scores. For ELL students, the assessment was translated into Spanish and items were presented visually and read aloud to reduce the influence of reading ability. Scratch paper and manipulatives were also provided for some items. Scores on this assessment were calculated using IRT procedures and were based on a total of 96 items. During the fall and spring of kindergarten, this assessment had reliability estimates of 0.92 and 0.94. Regarding validity evidence, the mathematics test specifications were based on NAEP mathematics frameworks, from which items were developed and reviewed by a panel of experts. Field tests then allowed for the selection of the best performing items for the final assessment (Tourangeau et al., 2015b).

Variables

Dependent variables. The primary dependent variables for this study were math performance and math growth, which were quantified in the ECLS-K:2011 dataset using item response theory (IRT). The dependent variable for the first research question, which examined variables related to math performance at kindergarten entry, was students' IRT scaled score on the mathematics assessment in the fall of kindergarten. To examine the second and third research questions, which looked at variables related to math growth across the kindergarten school year, mathematics gain scores were computed using the procedures defined by Tourangeau et al. (2015a). Specifically, a kindergarten gain score was calculated by subtracting students' fall mathematics IRT scaled score from their spring scaled score.

Independent variables. Several independent variables were examined to address the three research questions of the study. First, primary language proficiency (i.e., Spanish proficiency) and socioeconomic status (SES) were examined at kindergarten entry to answer Research Question 1. Primary language proficiency was defined as students' IRT scaled scores on the SERS assessment. Students' family SES was calculated by the publishers of the ECLS-K:2011 dataset as a continuous variable from five parent-reported components: both parents' education, both parents' occupational prestige, and household income (Tourangeau et al., 2015a).

Several variables related to classroom instructional strategies and skill emphases were used to answer Research Question 2, each of which were measured through teacher responses to a research questionnaire. First, the frequency of achievement grouping practices was measured on a 7-point scale from "never" or "less than once a week" to "one," "two," "three," "four," or "five days a week." Several additional variables related to specific instructional strategies were measured using a similar 6-point scale that included the options "never," "once a month or less," “two or three times a month,” “once or twice a week,” “three or four times a week,” or “daily.” The classroom frequency of each of the following strategies was measured using this scale: counting out loud, using geometric or counting manipulatives, playing math-related games, using measuring instruments, explaining and solving math problems, calendar-related activities, doing worksheets, solving real life problems, solving math with a partner, completing mixed group math work, and using a number line. In addition, how often a teacher focused on math skills most likely to be seen in kindergarten was measured using this same scale. These skills included: relation between number and quantity; writing numbers 1 to 10; counting by 2’s, 5’s, and 10’s; naming geometric shapes; identifying relative quantities; sorting into subgroups using a rule; ordering objects; making/copying patterns; adding single-digit numbers; subtracting single digit numbers, reading two-digit numbers; reading simple graphs; simple data collections and graphing; recognizing ordinal numbers; and estimating quantities. Finally, teachers reported how much time they spent using a non-English language for math class on a 5-point scale from “never” to “all of the time.” A third independent variable – computer use – was planned for inclusion in this analysis. Unfortunately, most participants (n = 260) were missing data related to this variable; therefore, it was necessary to remove it from analyses to maintain satisfactory statistical power.

Additional variables related to more systems-level school organization were used to answer Research Question 3. These variables included type of kindergarten program (i.e., all-day or half-day), as well as teacher-reported adequacy of available materials for teaching ELL students and for teaching math. These latter variables were measured using 4-point scales ranging from “never adequate” to “always adequate” and “I get none of the resources I need” to “I get all the resources I need,” respectively.

Analyses

Preliminary analyses. Preliminary analyses were completed to determine whether and to what degree a mathematics performance gap is present in the ECLS-K:2011 dataset between Hispanic ELL, Hispanic FEP, and White non-Hispanic FEP students. Specifically, three separate one-way analysis of variances (ANOVAs) were conducted to determine whether significant differences in math performance existed between these groups. Math IRT scaled and growth scores were used as dependent variables in these analyses.

Considerations. When conducting statistical analyses with large national datasets like the ECLS-K:2011, two important and related factors need to be addressed: the use of nonrandom sampling procedures and the impact of clustering (Hahs-Vaughn, 2005). In the case of the ECLS-K:2011 dataset, individuals were selected for voluntary participation using the three-staged probability sampling procedure described above. Because of these sampling procedures, students in the same schools and classrooms participated in the study, which is known as "clustering." Students in the same clusters are likely to be more similar to each other than students selected randomly from a national pool. Per Hahs-Vaughn (2005): "This type of sampling design creates challenges that must be addressed when performing statistical analyses to ensure accurate standard errors and parameter estimates" (p. 222).

To address these issues, two broad approaches are available: model-based and design-based. Model-based approaches (e.g., multilevel modeling) are appropriate when the clustering effect is relevant to the research question (Hahs-Vaughn, 2005). However, using multilevel modeling with unbalanced and sparsely clustered data (i.e., less than 5 observations per group) can lead to other problems including reduced statistical power (Clarke, 2008). The clustering present among ELL students in the ECLS-K:2011 dataset is unbalanced (ranging from 1 to 11 students per school), sparse (an average of 2.7 students per school), and includes relatively few groups (*n* = 127 schools). For these reasons, a design-based approach was chosen to deal with the issue of clustering.

Specifically, the method used for the present study involved creating what Hahs-Vaughn (2005) described as “design effect adjusted weights” (p. 226). A design effect, or DEFF, is defined by Tourangeau et al. (2015b) as “…the ratio, for a given statistic, of the variance estimate under the actual sample design to the variance estimate that would be obtained with [a simple random sample] of the same sample size” (p. 4-26). By incorporating DEFF into statistical analyses, researchers can approximate correct variance values (Tourangeau et al., 2015b). One way of incorporating DEFF into statistical analyses is by using it to compute a new weighting variable (Tourangeau et al., 2015b). This process involves first identifying the correct weighting variable to used, normalizing that weight, and finally dividing the normalized weight by an appropriate DEFF value to create a “design effect adjusted weight” (Tourangeau et al., 2015b; Hahs-Vaughn, 2005). Without this last step, analyses would likely underestimate true variance, leading to an increased likelihood of committing a Type I error (Clarke, 2008; Hahs-Vaughn, 2005).

As described previously, the specific weight selected for this study was W12AC0, which adjusts for both child assessment and teacher response data during both the fall and spring of kindergarten. These weight values were normalized by dividing individual weight values by the mean weight value. While many design effect values are available in the ECLS-K:2011 technical manual, no value specific to ELL students is provided. When no value for a subgroup is available, Hahs-Vaughn (2005) has recommended a conservative approach of using the average DEFF value for a larger subgroup. Such a value will likely overestimate the influence of clustering, because it is based on a larger sample size. For the present study, the average design effect value for all Hispanic students was used to calculate the design effect adjusted weights. Because of this conservative approach, a somewhat more liberal alpha level was selected ($\alpha = 0.05$).

Primary analyses. Similar to Valle et al. (2013), multiple regression analyses were used to answer each of the primary research questions. Unlike Valle et al. (2013), design effect adjusted weights were used to adjust for the effects of non-random and disproportionate sampling, as recommended by Tourangeau et al. (2015b) and Hahs-Vaughn (2005). To answer the first research question, math performance at kindergarten entry was predicted from Spanish language proficiency and SES. To answer the second research question, math growth across kindergarten was predicted based on the frequency of various instructional strategies and skill emphases detailed previously. Finally, the third research question examined math growth across kindergarten as predicted by student class type and teacher-reported adequacy of materials. The actual completion of these statistical analyses was done using SPSS IBM Statistics Version 24.

CHAPTER IV: RESULTS

Preliminary Analyses

Preliminary analyses were done to determine whether and to what degree a mathematics performance gap is present in the ECLS-K:2011 dataset between Hispanic ELL, Hispanic FEP, and White non-Hispanic FEP students. Hispanic ELL students had the lowest mean performance at both the fall and spring of kindergarten, while White non-Hispanic FEP students had the highest performance at both times. Specifically, Hispanic ELL students near the end of kindergarten performed, on average, only slightly better than White non-Hispanic FEP students near the beginning of kindergarten (mean scaled scores of 31.54 vs 30.25, respectively). In other words, Hispanic ELL students ended kindergarten nearly an academic year behind their White non-Hispanic FEP peers. Meanwhile, the performance of Hispanic FEP students fell approximately halfway between these two groups at both time points. For all groups, performance was more variable in the spring than in the fall, although this increase was most pronounced for Hispanic ELL students. To put these scores into context, national percentiles were calculated using the entire ECLS-K:2011 dataset with proper sample weighting applied. Based on those results, Hispanic ELL students were performing on average at the 12th and 16th national percentiles in the fall and spring of kindergarten, respectively. Meanwhile, Hispanic FEP students were performing on average at the 30th and 34th percentiles during this same period, while White non-Hispanic FEP students on average fell at the 51st and 52nd percentiles. The means and standard deviations of math performance for each of these groups can be found in Table 3 below.

Table 3.
Mathematics IRT Performance by Group

	Hispanic ELL (any race)		Hispanic FEP (any race)		White Non-Hispanic FEP	
	M	SD	M	SD	M	SD
<u>Time</u>						
Fall	17.35	7.41	24.30	8.45	30.25	10.20
Spring	31.54	10.54	38.24	9.65	43.43	11.92
<u>Growth</u>	14.19		13.94		13.18	

One-way ANOVAs were conducted to examine whether these groups differences were significant in the fall or spring, or in terms of growth across kindergarten. The results indicated significant differences in math performance between the groups in both the fall [F (2, 297) = 54.208, p = 0.000] and spring [F (2, 297) = 30.770, p = 0.000]. Post hoc comparisons using the Tukey HSD test indicated that each group's mean was significantly different from both other group means for both the fall and spring. In other words, Hispanic ELL students' mean performance was consistently significantly lower than that of Hispanic FEP students (p = 0.000 for both fall and spring) and White non-Hispanic FEP students (p = 0.000 for both fall and spring). In addition, the mean performance of Hispanic FEP students was significantly lower than the performance of White non-Hispanic students in both the fall (p = 0.000) and spring (p = 0.002). An additional one-way ANOVA was conducted to examine differences in mathematics growth across kindergarten. While Hispanic ELL students showed the greatest gains in math over the academic year (i.e., a gain of 14.19 points from fall to spring), differences in growth were not statistically significant [F (2, 297) = 0.464, p = 0.629]. This indicates that it is likely that each of these groups of students made similar levels of math growth across kindergarten.

Table 4.
One-Way ANOVA's with Math IRT Scores as Dependent Variables

	df's	*F*	*p*
Time			
Fall	2, 297	54.208	0.000*
Spring	2, 297	30.770	0.000*
Growth	2,297	0.464	0.629

Note: * denotes $p < 0.05$

Figure 1 below provides a visual depiction of math performance for these groups over time. As described above, the differences in the means for each of the groups was significant during both the fall and the spring. The differences in growth, however, were not. As depicted by the near parallel lines among the different groups, these students all demonstrated similar levels of growth over kindergarten.

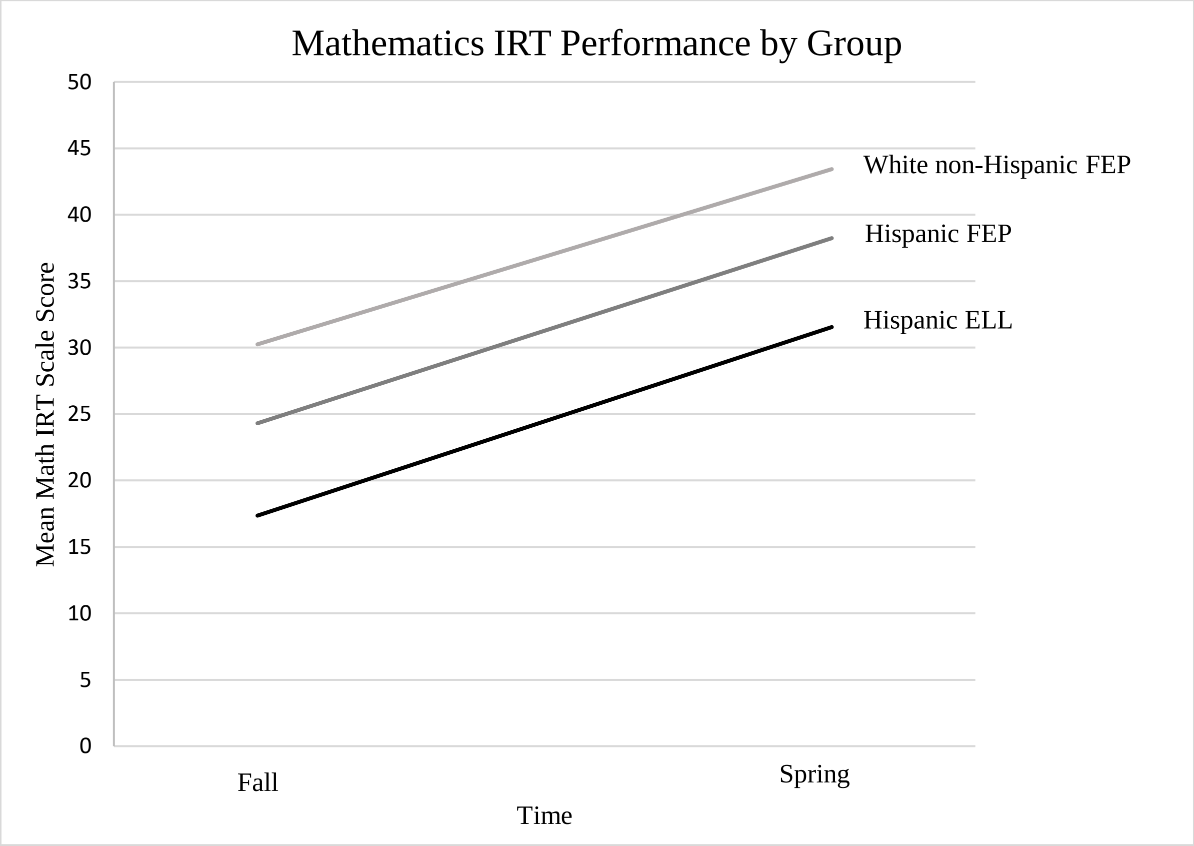

Figure 1. Math IRT Scaled Scores by group across kindergarten.

Primary Analyses

Assumptions

When conducting each of the analyses described below, several assumptions of multiple regression analyses were first tested. First, the data were examined for the influence of outliers. Next, standardized residual values were plotted against each predictor variable to ensure that non-linear patterns did not exist in the data. The assumption of homoscedasticity was assessed by plotting studentized residual values against standardized predicted values. The assumption of the absence of multicollinearity was examined through correlation matrixes. Finally, the assumption of normality was assessed through the examination of standardized residual histograms and P-P plots. Unless otherwise noted in the analyses below, each of these assumptions was met for each of the analyses.

Research Question 1

To answer the first research question, a multiple regression analysis was conducted to examine how math performance in the beginning of kindergarten was related to a child's SES and primary language performance (i.e., Spanish performance).

Independent variables. As noted in the previous chapter, children's SES was measured using a continuous variable calculated during ECLS-K:2011 data collection efforts as a combination of five parent-reported components: both parents' education, both parents' occupational prestige, and household income (Tourangeau et al., 2015a). Among ELL students, scores on this variable ranged from -2.330 to 0.400, with a mean of -1.076 and a standard deviation of 0.395. Spanish language performance was measured as an IRT scaled score on a 31-item Spanish Early Reading Skills (SERS) assessment. Scores on this measure ranged from 2.859 to 29.120 with a mean of 12.732 and a standard deviation of 5.385.

Assumptions. The only concern raised when assessing the assumptions for this analysis was multicollinearity between the two independent variables. While the correlation between these variables was significant ($p = 0.024$), the correlation coefficient was at an acceptable level ($r = 0.171$) to consider the assumption of no multicollinearity met.

Multiple regression. The multiple regression was significant [F (2, 130) = 143.033, p = 0.000] and explained a large proportion of the variance in mathematics performance during the fall of kindergarten ($R^2 = 0.688$). However, primary language performance was the only significant predictor ($t = 16.240$, $p = 0.000$); SES was not a significant predictor at the chosen alpha level ($t = 1.875$, $p = 0.063$). In other words, students who performed better on a test of early Spanish skills were predicted to perform better in math. These results are summarized in Table 5.

Table 5.
Multiple Regression Predicting Fall Math IRT Scaled Score

	β	*SE*	*t*	*p*
Continuous SES Measure	1.933	1.031	1.875	0.063
SERS IRT Scale Score	1.217	0.075	16.240	0.000*

Note: * denotes $p < 0.05$

Research Question 2

Two separate multiple regression analyses were conducted to answer the second research question, which sought to determine how educators can most effectively instruct Spanish-speaking ELL students in mathematics. The first multiple regression examined the effects of various instructional strategies on kindergarten math growth, while the second examined the effects of certain instructional emphases. Stepwise regression procedures were used for both analyses to optimize prediction accuracy.

Independent variables. As described in the previous chapter, several variables related to instructional strategies and specific math skills taught in the classroom were used as independent variables for these analyses. Information for most of these variables was collected through teacher-report using the scale outlined in Table 6. The only exceptions were the instructional strategies of using a non-English language and using achievement groups, which were collected using slightly different scales. Use of a non-English language for math was measured using the following scale, with the design effect adjusted weight value noted: never (n = 74), less than half the time (n = 34), about half the time (n = 11), more than half the time (n = 14), and all the time (n = 25). Use of achievement groups for math was measured using the following scale: never (n = 33), less than once a week (n = 14), one day a week (n = 7), two days a week (n = 15), three days a week (n = 13), four days a week (n = 18), and five days a week (n = 59).

Assumptions. When examining the assumptions for these analyses, multicollinearity posed the biggest concern. Several independent variables in both analyses were significantly correlated with each other. However, every significant correlation coefficient between instructional strategies was at or below r = 0.53, which did not raise concerns about violating this assumption. In terms of skills emphases, however, the variable of ordering objects was significantly and highly correlated with several other independent variables, posing multicollinearity concerns. Specifically, this variable was correlated with sorting objects into groups (r = 0.745; p = 0.000), making/copying patterns (r = 0.597; p = 0.000), identifying relative quantity (r = 0.493; p = 0.000), naming geometric shapes (r = 0.489; p = 0.000), estimating quantities (r = 0.461; p = 0.000), and recognizing ordinal numbers (r = 0.400; p = 0.000). Because of the high level of collinearity for this variable, it was removed from further analysis. The next highest correlation between independent variables was between adding and subtracting single digit numbers ($r = 0.568$; $p = 0.000$).

Table 6.
Frequency of Responses for Instructional Strategies and Skill Emphases

	Number of Days per Month			Number of Days per Week		
	Never	≤1	2 or 3	1 or 2	3 or 4	5
<u>Instructional Strategies</u>						
Count Out Loud	0	0	0	1	10	150
Geometric Manipulatives	0	9	17	59	41	36
Counting Manipulatives	0	4	4	29	60	64
Math-Related Games	2	6	18	43	34	59
Measuring Instruments	25	55	43	25	7	6
Explain/Solve Math Problems	5	13	20	25	41	67
Calendar-Related Activities	1	4	1	0	13	144
Math Worksheets	6	11	7	45	32	59
Solve Math with Partner	14	9	14	32	41	51
Solve Real-Life Math Problems	8	7	19	36	58	34
Mixed Group Math Work	19	5	9	37	38	54
Number Lines	13	13	14	37	39	45
<u>Skill Emphases</u>						
Number and Quantity Relation	3	1	4	15	45	92
Writing Numbers 1 to 10	6	3	8	24	44	72
Counting by 2's, 5's, 10's	17	3	6	29	22	84
Naming Geometric Shapes	8	5	22	36	38	50
Identifying Relative Quantity	3	4	14	46	48	42
Sorting Subgroups Using Rule	7	9	32	53	35	24
Ordering Objects	7	13	34	52	31	24
Making/Copying Patterns	5	5	30	36	33	49
Add Single-Digit Numbers	1	5	14	41	37	61
Subtract Single-Digit Numbers	7	18	18	40	30	41
Reading Two-Digit Numbers	14	5	10	17	25	88
Reading Simple Graphs	6	16	41	50	18	28
Simple Data Collection/Graph	9	21	46	44	17	20
Recognizing Ordinal Numbers	12	22	33	37	22	32
Estimating Quantities	20	31	40	33	21	13

Multiple regressions. The results of the first multiple regression analysis indicated that a model including only the frequency of playing math-related games as a predictor variable explained a significant, but small ($R^2 = 0.033$), proportion of the variance in kindergarten math growth among Spanish-speaking ELL students [F (1, 132) = 4.520, $p = 0.035$]. No other instructional strategy (i.e., use of achievement grouping, counting out loud, geometric manipulatives, counting manipulatives, measuring instruments, explaining/solving problems, calendar-related activities, math worksheets, solving math problems with a partner, solving real-life math problems, mixed group math, number lines, and bilingual instruction) was a significant predictor of kindergarten math growth. These results are shown in Table 7.

Table 7.
Multiple Regression Predicting Math IRT Growth from Instruction

	β	*SE*	*t*	*p*
Frequency Math-Related Games	1.213	0.570	2.126	0.035*

Note: * denotes $p < 0.05$

The second multiple regression analysis found that only a model including the instructional emphasis of recognizing ordinal numbers explained a significant, but also small (R^2 = 0.085), proportion of the variance in math growth among Spanish-speaking ELL students [F (1, 130) = 12.051, p = 0.001]. In other words, students who spent more time working on recognizing ordinal numbers experienced greater growth in math across kindergarten. None of the other math skills commonly taught in kindergarten (i.e., relation between number and quantity; writing numbers 1 to 10; counting by 2's, 5's, and 10's; naming geometric shapes; identifying relative quantities; sorting into subgroups using a rule; ordering objects; making/copying patterns; adding single-digit numbers; subtracting single digit numbers; reading two-digit numbers; reading simple graphs; simple data collections and graphing; and estimating quantities) were significant predictors of kindergarten math growth.

Table 8.
Multiple Regression Predicting Math IRT Growth from Emphases

	β	*SE*	*t*	*p*
Recognizing Ordinal Numbers	1.502	0.433	3.472	0.001*

Note: * denotes $p < 0.05$

Research Question 3

The final research question explored the influence of more systems-level education decisions on Spanish-speaking ELL kindergarteners' mathematics performance. Specifically, a multiple regression analysis was conducted to explore how math growth was related to teacher-reported adequacy of materials and student class type (i.e., all-day or half-day kindergarten).

Independent Variables. As shown in Table 9, most students were enrolled in full-day kindergarten programs. In addition, most teachers felt that their materials were either mostly or totally adequate for teaching math and for teaching ELL students specifically.

Assumptions. Although the two variables related to adequacy of materials were significantly correlated (r = -0.410; p = 0.000), the coefficient was not of a magnitude that would raise concerns about violating the assumption of no multicollinearity.

Multiple Regression. A model including teacher-reported adequacy of materials and program type as predictors did not explain a significant proportion of the variance in ELL student's kindergarten math growth [F (3, 136) = 1.603, p = 0.192]. The predictor that most closely approached significance was child class type (t = -1.798, p = 0.074), with all-day kindergarten programs being associated with more growth. More detailed results are provided in Table 10.

Table 9.
Frequency of Responses for Systemic Variables

	f
Child Class Type	
Full-Day	136
Half-Day	27
Adequacy of Materials for Math	
I get all the resources I need	73
I get most of the resources I need	65
I get some of the resources I need	23
I get none of the resources I need	0
Adequacy of Materials for ELL's	
Always adequate	84
Sometimes not adequate	43
Often not adequate	22
Never adequate	6

Table 10.
Multiple Regression Predicting Math IRT Growth

	β	SE	*t*	*p*
Adequacy of Math Supplies	-1.157	1.040	-1.113	0.268
Adequacy of Materials for ELL Students	-0.612	0.874	-0.700	0.485
Child Class Type	-3.306	1.838	-1.798	0.074

Note: * denotes $p < 0.05$

Summary

The results of the preliminary analysis indicated that there is a significant gap in the mathematics performance of Hispanic ELL, Hispanic FEP, and White non-Hispanic FEP students. This gap exists at kindergarten entry and persists through the spring of kindergarten. Differences in growth over kindergarten among these groups were not statistically significant, therefore it is unlikely that progress was made in closing this performance gap during kindergarten.

With regard to the primary analyses, a multivariate regression model predicting math performance at kindergarten entry from students' primary language proficiency and SES was significant, although primary language proficiency was the only significant predictor. In addition, models predicting math growth over kindergarten from the instructional strategy of playing math-related games and the skill emphasis of recognizing ordinal numbers were significant. Finally, a multivariate regression model predicting math growth from the adequacy of instructional materials and student program type was not significant.

CHAPTER V: DISCUSSION

According to NAEP data, little progress has been made in addressing the ongoing performance gap in mathematics between ELL and FEP students (U.S. Department of Education, 2015c). Available research in this area has demonstrated positive relationships between early mathematics performance, socioeconomic status (Krashen & Brown, 2005; Roberts & Bryant, 2011), and primary language proficiency (Guglielmi, 2012). In terms of classroom instruction, previous research has supported the use of high-quality computer programs (Kim & Chang, 2010), heterogeneous achievement grouping (Chang et al., 2009), bilingual instruction (Burchinal et al., 2012), and the implementation of more cooperative and fewer teacher-centered activities (Chang, 2008; Valle et al., 2013). In addition, ELL students have been shown to benefit from all-day kindergarten programs and from school settings that have access to more resources. However, these findings are based on limited and dated research, typically using student data that is over a decade old (Chang, 2008; Chang, 2012; Chang et al., 2015; Chang et al., 2009; Guglielmi, 2012; Halle et al., 2012; Han & Bridglall, 2009; Kim & Chang, 2010; Roberts & Bryant, 2011; Valle et al., 2013). Because the ELL student population and the education system itself are constantly changing, it is necessary for research in this area to remain current. The purpose of this study was to use recently collected national data to better understand the mathematics performance of Spanish-speaking ELL students – the largest group of ELL students in the United States.

Specifically, this study examined Spanish-speaking ELL student data from the ECLS-K:2011 dataset to identify which Spanish-speaking ELL students may be at risk for mathematics difficulties in kindergarten by examining the relation between initial mathematics performance and primary language proficiency and socioeconomic status. In addition, the current study evaluated which instructional strategies (i.e., use of achievement groups and computers), skill emphases (e.g., writing numbers, naming shapes), and school factors (i.e., all-day vs. half-day kindergarten, school resources) were associated with improvements in mathematics performance across kindergarten. These questions were explored using multivariate regression analyses.

Findings

Preliminary Analyses

Preliminary analyses were completed to determine whether a significant performance gap exists in the ECLS-K:2011 dataset. While the original ECLS-K dataset showed a significant initial gap in mathematics performance at kindergarten entry (Chang, 2012; Han & Bridglall, 2009; Kim & Chang, 2010) that persisted or grew larger over time (Chang, 2012; Kim & Chang, 2010), updated research using this more recent dataset is not available. To examine whether such a gap exists, three separate one-way ANOVA's were conducted to compare mathematics performance in the fall and spring of kindergarten using 100 randomly-selected participants from each of the following groups: Hispanic ELL, Hispanic FEP, White non-Hispanic FEP. Results showed that significant differences in mean performance existed between each of these groups at both time periods. Hispanic ELL students scored significantly below Hispanic FEP and White non-Hispanic FEP students in both the fall and spring of kindergarten. In addition, Hispanic FEP students scored significantly higher than Hispanic ELL students, but significantly lower than White non-Hispanic FEP students. While potential causes of this gap were not examined in the current study, this would be an important area for future research. For example, differential exposure to preschool education among these groups may contribute to the initial gap in performance. Similarly, group differences in parental expectations regarding math prior to kindergarten may also contribute to an initial gap in math performance (Cannon & Ginsburg, 2008).

While Hispanic ELL students made slightly more growth on average than students in the other two groups, differences in growth were not statistically significant. This indicates that while students in these groups made similar levels of growth in kindergarten, because Hispanic ELL students started kindergarten significantly behind their FEP peers (both Hispanic and White non-Hispanic), they remained significantly behind those peers at the end of kindergarten. The current results, which demonstrate a significant gap in mathematics performance between ELL and FEP students, are consistent with those found by other researchers using other datasets (Chang, 2012; Han & Bridglall, 2009; Kim & Chang, 2010; Ockey, 2007). Furthermore, the non-significant differences in growth are consistent with the results of Chang (2012) and Kim and Chang (2010), who found that this gap in performance persisted over time. Given consistent findings of a performance gap between these groups of students, it is expected, but disappointing, to see this gap demonstrated again.

Primary Analyses

The first research question explored how math performance in the fall of kindergarten is related to primary language proficiency (i.e., Spanish proficiency) and a student's SES. The result of a multivariate regression model predicting fall math performance from these variables was significant. This indicates that students' primary language proficiency and SES explain a significant proportion of the variance in how well they do in math at the beginning of kindergarten. Furthermore, these two variables accounted for a large proportion of the variance in math performance ($R^2 = 0.688$). In other words, students with higher Spanish proficiency and of higher SES backgrounds performed better in math when they entered kindergarten. It should be noted, however, that Spanish proficiency was the only significant predictor at the chosen level of alpha. These results are consistent with those of Guglielmi (2012), who found that, for Hispanic ELL students, primary language proficiency predicted mathematics performance. Although other researchers have identified significant positive associations between SES and math performance among ELL students (Krashen & Brown, 2005; Roberts & Bryant, 2011), this was not a significant predictor in the current model. This was perhaps influenced by the restricted range of SES levels represented in the ELL sample.

The second research question examined which classroom strategies were associated with growth in math across kindergarten. This question was broken down into two separate analyses. The first analysis predicted student math growth from various instructional strategies (i.e., use of achievement grouping, counting out loud, geometric manipulatives, counting manipulatives, measuring instruments, explaining/solving problems, calendar-related activities, playing math-related games, math worksheets, solving math problems with a partner, solving real-life math problems, mixed group math, number lines, and bilingual instruction). The second analysis predicted student math growth based on which math skills teachers emphasized in their classroom (i.e., relation between number and quantity; writing numbers 1 to 10; counting by 2's, 5's, and 10's; naming geometric shapes; identifying relative quantities; sorting into subgroups using a rule; ordering objects; recognizing ordinal numbers; making/copying patterns; adding single-digit numbers; subtracting single digit numbers, reading two-digit numbers, reading simple graphs; simple data collections and graphing; and estimating quantities).

The results of the first analysis showed that the most parsimonious model for explaining kindergarten math growth from instructional strategies included only the frequency of playing math-related games as a predictor. This variable was positively associated with math growth, meaning that students who made greater growth in math more frequently played math-related games in their classrooms. Although playing math-related games explained only a small amount of the variance in math growth (R^2 = 0.033), this result is consistent with previous recommendations for working with ELL students. Furner et al. (2005) recommended using more cooperative, collective strategies, as opposed to teacher-centered instruction, when working with ELL students. In this sense, playing mathematics games, which are often interactive, may be more culturally supportive of ELL students than other types of teacher-centered instruction or independent work. Interestingly, the use of bilingual instruction was not significantly predictive of math growth, as was seen by Burchinal et al. (2012). However, that study specified that the positive impact of Spanish instruction was only found in high-quality education settings, a qualification not evaluated in the current study. When examining the results across all education settings, as the current study did, those authors found no significant association between Spanish instruction and math performance. The different results between these two studies could also be influenced by the way teachers' Spanish use was measured in the two studies (i.e., direct observation vs. teacher-report). Finally, a limitation of both studies was the low rates of Spanish instruction found in the samples. In the Burchinal et al. study, more than 25% of students received no Spanish instruction. In the current study, almost 50% of Spanish-speaking ELL students received no Spanish instruction.

Regarding specific skills emphasized in the classroom, the second analysis found that predicting math growth from the frequency of instruction on recognizing ordinal numbers was the most efficient and significant model. In other words, students who spent more time practicing the skill of recognizing ordinal numbers made more math growth in kindergarten. However, this model explained only a small proportion of the variance in math growth (R^2 = 0.085). According to Clements (2004), learning ordinal numbers is an important part of early math development for children between 2 and 7 years old. Because this skill is developed in increasing complexity across childhood (i.e., from preschoolers learning concepts like “first” and “last” to second graders learning concepts like “thirteenth”), it would likely be relevant to ELL kindergarteners of a range of ability levels. This is in contrast to higher level skills that kindergartners may not have the foundation for, such as addition and subtraction, which Clements (2004) identified as a skill expected of second graders. To put it another way, the reason ordinality was identified as an important skill for ELL student math growth may be because it is a foundational skill developed across early childhood that can help “…build on children’s concrete comparing and knowledge of counting words” (p. 30).

Finally, the third research question explored the influence of classroom resources and program type (i.e., all-day or half-day) on kindergarten math growth. In this analysis, neither variable significantly predicted math growth among ELL students. Program type most closely approached significance as a predictor ($p = 0.074$), with all-day kindergarten programming associated with greater math growth than half-day programming. This result is consistent with that of Chang (2012), who found non-significant effects of all-day vs. half-day kindergarten when comparing ELL students of all racial/ethnic groups across all SES backgrounds. However, that study did find a significant impact of program type among low-SES ELL students.

With regard to program resources, neither the adequacy of math supplies, nor the adequacy of materials for teaching ELL students were significant predictors of math growth. These results are inconsistent with those of Han and Bridglall (2009), who found that students in schools with greater resources made greater growth in math. The differing results may be due in part to the way the variables were defined in these two studies. Those authors measured school resources using a combination of school type (i.e., public or private), minority/low-income student population, and the quality of school facilities (e.g., cafeteria, computer lab). This latter variable was assessed through the responses of a school administrator. The current study assessed these variables through teacher-reported adequacy of materials. In other words, this variable was measured at a school level by previous research and at a classroom level by the current research. It is possible that the different perspectives of teachers and administrators contributed to the different results obtained in these two studies.

Implications

Schools and school districts have a responsibility to identify and support students most at risk for school failure. Despite this obligation and years of research demonstrating a consistent gap in performance, ELL students reliably perform below their FEP peers in the area of mathematics. The results of this study contribute to the evidence of this gap, this time in the recently collected ECLS-K:2011 dataset. In this data, a significant performance gap persisted throughout kindergarten. The lack of significant differences in growth between ELL and FEP students provides no indication that this gap will close. Furthermore, the average Hispanic ELL student in this sample finished kindergarten with performance closer to that of White non-Hispanic FEP students beginning kindergarten; they were almost an academic year behind those peers in terms of mathematics performance. These points help illustrate the need for effective strategies to identify students who would benefit from early intervention, as well as to identify effective methods for instructing those students.

Based on the results of this study, Spanish-speaking ELL students who enter kindergarten with lower Spanish performance may also demonstrate lower math performance. For such students, early intervention in both language and math will likely be beneficial. However, a mathematics assessment conducted in Spanish will help identify which students may or may not need such support.

As described above, the classroom strategies that significantly predicted kindergarten math growth in this study were playing math-related games and focusing on the skill of recognizing ordinal numbers. It may be that math-related games provide a more culturally-relevant, interactive format for learning math skills than some other instructional strategies (e.g., completing math worksheets), particularly for ELL kindergartners whose math performance may be more similar to early or pre-kindergarten FEP children. In addition, a classroom emphasis on recognizing ordinal numbers may be particularly relevant to ELL kindergarteners, as this is an important foundational math skill for students at a variety of developmental levels (Clements, 2004). Although, it should be noted, both of these variables explained only a small proportion of the variance in math growth in the current study.

Finally, although the effects of all-day vs. half-day instruction and classroom resources were not significant in this study, previous research has identified these factors as important contributors to ELL student math growth. While the results of this study found no significant impact of program type for students across SES levels, Chang (2012) found that for ELL students of low-SES backgrounds, attending an all-day kindergarten program was associated with greater math growth. In addition, Han and Bridglall (2009) found that attending a school with more resources was associated with higher math growth for ELL students. Considering these results together, it may be that ELL students in schools with more resources are able to make considerable math growth even from a half-day program, whereas ELL students from low-SES backgrounds (who are likely in schools with fewer resources) in particular benefit from the additional time spent in school. Future research should further examine the interaction between students' SES, school/classroom resources, and program type, and how those interactions impact math growth.

Limitations

Several limitations should be considered when assessing the results and implications described above. With regard to the preliminary analyses, because the sampling procedure was modeled after those of Valle et al. (2013), the same limitations of that study apply here. Specifically, the use of a systematic stratification procedure for drawing a sample limits the generalizability of the findings, because the sample used for analysis was no longer nationally representative. Furthermore, the different groups in the preliminary analyses (i.e., Hispanic ELL, Hispanic FEP, and White non-Hispanic FEP) took different versions of the math test. This raises concerns about the comparability of scores on the dependent variables. As described in Chapter 3, FEP students took the math test in English, while Spanish-speaking ELL students took a translated version of the same test in Spanish.

As described in the previous section, there were several limitations to the primary analyses as well, including restricted representation among some variables (e.g., SES and frequency of non-English instruction) and limitations due to the reliance on teacher-reported data. In addition, this study used a conservative method for selecting ELL students. To qualify for selection in this study, kindergarten Spanish-speaking ELL students needed to fail a preschool-level English screening test. Other researchers using the original ECLS-K dataset have used more liberal identification procedures. For example, Han and Bridglall (2009) identified ELL students based entirely on their reported primary home language, a procedure that carried its own limitations. A more conservative selection procedure was chosen for this study to ensure that all ELL students included in the primary analyses completed the same version of the math test. However, this means that the results of this study are based on a sample of ELL students with less than preschool level English skills. This is something that must be considered when making generalizations to the population of all Spanish-speaking ELL students.

It was also noted in Chapter 3 that the analyses used design effect adjusted sample weights based on the average reported design effect for Hispanic students. This was the strategy recommended by Hahs-Vaughn (2005), although it was noted that this was likely to be a conservative approach. The use of a larger design effect than may have been necessary would increase the standard error used in analyses and therefore decrease statistical power, making it harder to reject the null hypothesis. This may have contributed to the fact that some significant relations found in previous research were not observed in the present study (e.g., the influence of SES or bilingual instruction).

Conclusions

Despite these limitations, this research made several important contributions to the literature on ELL math development. First, the results replicated the commonly observed gap in mathematics performance between ELL and FEP students, this time in a more recently-collected dataset than previous literature has used. Second, by using a large-scale dataset, the results provide insight into current strategies for effectively identifying and instructing Spanish-speaking ELL students. Because ELL students are a diverse and constantly changing population, and because schools have a responsibility to identify and support them, it is important that research on best practices in this area remain current. Based on the results of this study, Spanish-speaking ELL students who enter kindergarten with lower early language performance (in both Spanish and English) may benefit not only from early literacy intervention, but math intervention as well. In addition, these results provided some insight into what classroom strategies are associated with more math growth for these students. Specifically, playing math-related games and focusing on the skill of recognizing ordinal numbers were positively associated with math growth.

These results should be considered in light of both the limitations described above and the important contribution of individual differences. Future research should examine how these and other strategies are differentially effective based on within-group differences. For example, as described above, how interactions between SES, school/classroom resources, and program type impact ELL students' math growth. In addition, the current research was limited by the data source to examining only the math performance of Spanish-speaking ELL students. Future research is needed to identify whether these results hold for other groups of ELL students. The current dataset also contained limited representation among certain variables expected to influence math performance (e.g., SES, bilingual instruction, computer use). Another potential area for future research would be to examine the impact of these variables in a more systematic way. While the results of this study have important implications, one final conclusion is that additional and consistent research in this area is necessary to ensure that ELL students have and continue to have their educational needs met.

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