Summary Report from the National Science Foundation (NSF) (2017-2022): Mathematical Growth Among English Learners at Risk and Not at Risk for Math Difficulties

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Importance of the Study

Although math instruction for native English-speaking children has a strong research base, much less is known about effective teaching for English Learners (EL). The sparse research is troubling because this group continues to have a high dropout rate, low achievement scores, high mobility, and high poverty (National Center for Education Statistics, 2022). Further, mathematic skills are necessary for future academic success, career aspirations of higher prestige, and overall higher earning potential. According to the National Assessment of Educational Progress, 70% of ELs in the United States scored below basic and 7% were at or above proficient in 4th-grade math. By 8th grade, 71% percent of ELs were below basic and just 3% scored at or above proficient in math. A major challenge for ELs is not only overcoming a language barrier but also overcoming low academic achievement. English learners continue to be at a disadvantage because they often have not yet developed age- or grade-appropriate proficiency in speaking, reading, or writing in English. The reason behind the prevalence of low achievement in ELs with Spanish as a first language in the U.S. public school system is unclear, because neither a method for accurate identification nor a consistent definition exists across states. Although low achievement is traditionally defined as not meeting a certain cut-off point across grades on normed-referenced tests, these cut-off points vary across school districts and states. For example, some states/districts define low mathematical achievers as the students who score consistently below the 25th percentile on standardized tests. These challenges underscore the need for a better method for accurately identifying EL children at risk for academic difficulties so targeted intervention can be provided.

Thus, this NSF study had two major objectives:

(1) Identify the cognitive processes of children who excel and those who consistently fail in math performance among Spanish-speaking children who are learning English as a second language.

(2) Determine those cognitive and instructional variables that mediate (i.e., positively influence) this relationship so effective instruction can be developed.

Overview of Procedures

This was a five-year longitudinal project (2017 - 2022). The research sites were in New Mexico and California and included over 400 elementary-age students who spoke Spanish as their first language. All children were enrolled in two-way dual language immersion programs, in which the instruction was delivered in Spanish and English. Ninety-five percent of the children participated in a federally funded lunch program. At each of the research sites, students began Grade 1 with 80% Spanish language instruction and 20% English instruction. Each year, English language instruction increased, with 70% Spanish and 30% English in second grade. By third grade, students received 50/50 English-Spanish language instruction.

To this end, EL children in Grades 1, 2, and 3, at the first round of testing, were administered a

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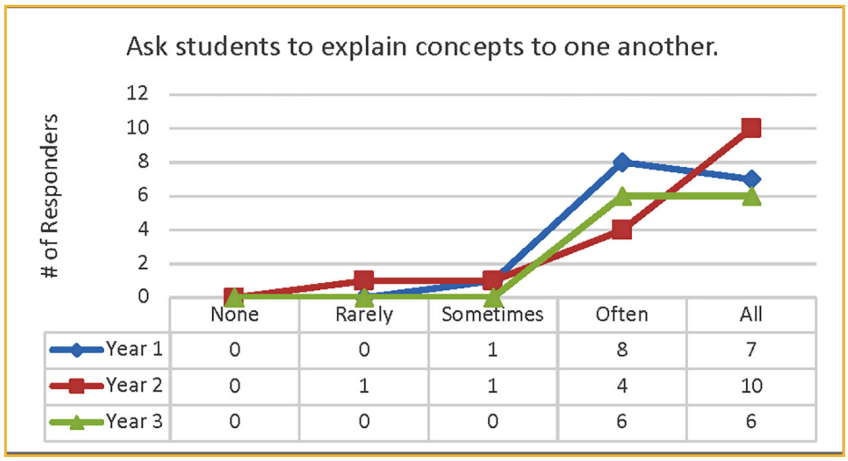
battery of math, reading, vocabulary, and cognitive (short-term memory [STM], working memory [WM], rapid naming (timed naming of letters and numbers in order), and inhibition (timed naming of numbers and letters out of sequence) measures in both English and Spanish. The battery of tests was administered again one year and two years later to the same participants. In addition, classroom math instruction was observed throughout the project, teachers completed behavior ratings on children, and provided information on instructional practices. In terms of comprehensiveness, this study had the largest array of Spanish and English measures that cover areas of math, reading, language, and cognitive processing when compared to other nationally recognized longitudinal studies on EL children to date. Other studies have primarily focused on English proficiency measures and/or are limited to one academic domain such as reading.



The study looked at key instructional activities that increased students' later math performance.

Some Conclusions from the Study?

Although the study results are still being analyzed, we can provide five general findings. The results are organized in terms of the topic, why the finding was important, how the information was gathered, and the finding(s) that emerged.

Finding 1:

Key instructional activities that increase EL children's later math performance on normative math measures were identified.

Why important? Although several classroom instructional activities (e.g., explicit instruction, peer interaction, instructional scaffolds) are expected to enhance EL children's classroom performance, the significant association between these classroom activities and Spanish-speaking EL children's achievement on normative measures in subsequent grades has not been established. More importantly, no published studies have determined those instructional components that influence EL children's later math (subsequent grades) performance. This is important for establishing instructional practices across grade levels and to build on skills from one grade to the next.

Our Approach. We developed an observation form that determined the frequency of instructional activities (e.g., instructional scaffolds, teaching algorithms, explicit instruction, peer interaction) that were significantly related to later normative achievement measures and cognitive scores. Multiple classroom observations were conducted in the first-year testing period across three time points (fall, winter, and spring).

Finding. Two major findings emerged. First, strategy instruction, peer interaction, and explicit instruction in the first year uniquely predicted norm-based English mathematical problem-solving scores in second year. These findings emerged even when grade level, vocabulary, reading, and calculation were accounted for. Second, children with math difficulties were less likely to be in classrooms in which the teacher used frequent instructional activities related to strategies, explicit instruction, and peer interactions than average-achieving children.

Li, J., Arizmendi, G. D., & Swanson, H. L. (2022). The influence of teachers' math instructional practices on English learners' reading comprehension and math problem-solving performance in Spanish and English. *International Journal of Bilingual Education and Bilingualism*, *25*(10), 3614-3630. doi:https://doi.org/10.1080/13670050.2022.2068346

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Swanson, H. L., Kong, J., Li, J., & Petcu, S. D. (2022). The relationship between early classroom activities and English language learners' later math problem-solving performance: An exploratory study. *Learning Disabilities Research & Practice, 37*(4), 242-261. doi:https://doi.org/10.1111/ldrp.12280

Finding 2:

Key cognitive measures that underlie math difficulties were identified so that instructional intervention could be developed.

Why important? One of the key areas in math found particularly difficult for EL students whose first language is Spanish is solving mathematical word problems. For example, consider solving a word problem such as, "15 dolls are for sale. 7 dolls have hats". The dolls are large. How many dolls do not have hats?" Children must access pre-stored information (e.g., 15 dolls), access the appropriate algorithm (15 minus 7), and apply problem-solving processes to control its execution (e.g., ignore the irrelevant information). Given the multi-step nature of math word problems, the cognitive mechanisms in solving these problems need to be identified so effective instruction can be developed.

Our Approach. A large battery of measures to pinpoint strength and difficulties in children at risk and not at risk across three years was administered. As expected, EL children not at risk for math difficulties outperformed children with math difficulties on a host of measures. Significant difficulties were found on both English and Spanish measures of reading, numeracy (judging which numbers are smaller or larger (146 vs. 164), math estimation (e.g., judging on a linear line that varies from 0 to 100 where a number (e.g., 25) resides, vocabulary, naming speed (quickly naming letters and numbers), short-term memory, and working memory (WM) across all grades and the three testing waves. These findings were not helpful because they do not identify those measures that uniquely underlie such children's processing difficulties. Thus, further analysis was necessary that took into consideration context (classroom), age, the cohort they were in, school, etc.

Finding. We identified those cognitive processes that uniquely underlie math difficulties in EL children. From a large array of English and Spanish measures, one of the key cognitive processes that predict math difficulties was growth on measures of executive processing (working memory). These measures were robust in predicting math difficulties even when the influence of English and Spanish measures of vocabulary, reading, and/or computation proficiency was controlled for. Working memory is defined simply as the general ability to monitor the recall of relevant information and inhibit (or suppress) irrelevant information.

Does WM have relevance to everyday learning? It does. For example, holding a person's address in mind while listening to instructions about how to get there, listening to a sequence of events in a story while trying to understand what the story means, locating a sequence of landmarks on a map while determining the correct route, listening to specific word features in the context of multiple words, and so on. All these tasks have some aspects of interference (a competing memory trace that draws away from the targeted memory trace) and monitoring (decisions related to the allocation of attention to the stimulus that is under consideration together with the active consideration of several other stimuli).

Swanson, H. L., Arizmendi, G. D., & Li, J. (2022). What mediates the relationship between growth in math problem solving and working memory in English language learners? *Journal of Educational Psychology, 114*(7), 1608-1632. doi:https://doi.org/10.1037/edu0000718

Swanson, H. L., Arizmendi, G. D., & Li, J. (2021). Working memory growth predicts mathematical problem-solving growth among emergent bilingual children. *Journal of Experimental Child Psychology, 201*, 33. doi:https://doi.org/10.1016/j.jecp.2020.104988

Finding 3:

Key cognitive processes that predict late-emerging math difficulties were identified.

Why important? Some EL children are relatively proficient in the early stages of learning to solve mathematical word problems, but experience math difficulties in subsequent years. This study determined those measures that significantly increased the odds of correctly identifying children

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with late-emerging math difficulties.

Our Approach. The study sought to identify the significant growth parameters that increased the odds of identifying late-emerging math difficulties in children relative to children with stable math deficits (low performance across all three years of testing in both English and Spanish). Children defined as late-emerging at risk are those with average math scores (> 25th percentile on normative measures) in the first year of our study, but fall below the 25th percentile in testing waves 2 and 3. Thus, we compared average EL achievers (scores in English and Spanish math above the 25th percentile for all three testing waves), children with persistent math difficulties (< 25% all three years), to late-emerging children with math difficulties.

Finding. When compared to average EL achievers, late-emerging math difficulties children showed weakness on measures of English reading, Spanish estimation, Spanish STM, and Spanish WM. Thus, predictors of later problems in math problem-solving are significantly related to performance in three Spanish measures (estimation, short-term memory, and working memory) and one English measure (reading).

Swanson, H. L., Arizmendi, G. D., & Li, J. (2023). Emergent math difficulties among English learners: Can the odds be reduced? *Child Neuropsychology, 29*(1), 136-164. doi:https://doi.org/10.1080/09297049.2022.2073987

Swanson, H. L., Kong, J., & Petcu, S. D. (2023). Stability of learning disabilities, cognitive growth, and L1 in English learners: A latent class and transition analysis. *Journal of Educational Psychology, 115*(3), 379-404. doi:https://doi.org/10.1037/edu0000771

Finding 4:

The key processes that separate language acquisition difficulties from math difficulties were identified.

Why important? Controversy exists as to whether EL children are under or overrepresented in special education. Can children at risk for serious learning difficulties in math be separated among a heterogeneous sample of children who are English learners?

Our Approach. Using procedures that take growth into consideration, we identified four distinct types of achievers: (a) balanced (proficient in both English and Spanish) bilinguals-average achievers, (b) unbalanced bilinguals (more proficient in Spanish than English) average achievers, (c) children at risk for learning difficulties, and (d) children with low Spanish and English vocabulary. The study estimated that 20% of our total sample was at risk for learning difficulties in the first testing wave, with late-emerging academic difficulties increasing to 5% at the later testing waves.

Finding. This study identified children at risk for learning difficulties who are struggling with second language acquisition. Classroom math instruction was primarily in Spanish. The key measures that separated the groups were three Spanish measures (short-term memory, inhibition, and working memory). Children with learning difficulties were weaker in performance compared to children who varied in English language acquisition on these measures.

Swanson, H.L., Kong, J., Petcu, S., & Pimentel, M. (2020). Can language acquisition be separated from learning disabilities? *Exceptional Children*, 86, 293-309

Swanson, H. L., Arizmendi, G. D., & Li, J. (2021). The stability of learning disabilities among emergent bilingual children: A latent transition analysis. *Journal of Educational Psychology, 113*(6), 1244-1268. doi:https://doi.org/10.1037/edu0000645

Finding 5:

The profile of EL children who are precocious (gifted) in math was identified.

Why important? Few studies have focused on EL children who excel in math computation. That is, although several studies have examined individual differences in EL children's mathematical performance in the elementary grades, few studies have focused on math-advanced elementary school-age children, especially among those children who are emergent bilinguals (EB). To our knowledge,

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no published studies have investigated the cognitive characteristics of mathematically gifted EL children across a broad array of measures in the child's first (Spanish) and second (English) language. Previous studies' inability to identify a cognitive profile of young EB children who are gifted in math processing has likely been due to issues in assessment. Factors related to language proficiency, cultural and linguistic background, acculturation, and socioeconomic status (SES) of EL students, test administration methodology (e.g., translations, availability of bilingual examiners), and the assessment instruments used with EL students (e.g., not included in the norm sampling group, differentiating low language proficiency from low achievement or ability) have all played a role in determining the scope of early investigations.

Our Approach. Although our research focus was on mathematical problem-solving, some children yielded high (> 98th percentile) scores on norm-based computation measures. Our first testing wave compared mathematically gifted children in computation to children who were average math achievers or low math achievers in computation.

Finding. The comparison of the groups (gifted, average, low computation) yielded several significant differences on a multitude of measures. However, only a few variables played a unique role towards increasing the likelihood of identifying mathematically gifted EL children. The first-year results indicated that the likelihood of identifying gifted children among EL children in math computation was related to measures of fluid intelligence, English estimation, Spanish problem-solving, and English working memory. Thus, in contrast to our hypothesis that mathematical giftedness in EL children would be tied primarily to the first language (Spanish), our results also suggested the cognitive measures for predicting gifted achievers also emerged on measures administered in English. In sum, cognitive measures that included estimation (e.g., judging on a linear line that varies from 0 to 100 where a number (e.g., 25, resides) and working memory in English, and problem-solving in Spanish were unique predictors that significantly influenced whether a child was categorized as gifted relative to average achievers.

Swanson, H. L. Kong, J. & Lussier, C. (2023-in press). Cognitive processes that underlie mathematically gifted emergent bilinguals. *Journal of Experimental Child Psychology.*

Our analysis of the data is continuing. We hope to share our analyses in a later Soleado article. Additionally, we are currently focused on developing and testing a cognitive strategy math problem-solving intervention for use in elementary classrooms. A list of published work for each finding and work in progress can be obtained from Dr. Petcu at *spetcu@unm.edu* or *spetcu@ku.edu* and Dr. Swanson at *hlswanson@unm.edu* or *Lee.Swanson@ucr.edu*.

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