A Longitudinal Study Examining the Impact of the Fueling Brains Program on Pre-Kindergarten and Kindergarten Student Achievement

ABSTRACT

This quasi-experimental study examined the impact of Fueling Brains, an executive function-focused early childhood program, on young children's literacy and mathematics skills. This two-year study followed pre-kindergarten students from an economically disadvantaged, high-minority district in Southeast Texas. A matched sample of students in the Fueling Brains program were academically compared to students in a traditional academic-focused program. **Findings indicated that students who participated in the Fueling Brains program academically outperformed those in the traditional academic-focused program on the rapid vocabulary and phonological awareness subtests of the CIRCLE Progress Monitoring System.** The effects of participation in the Fueling Brains program were lasting.

By the end of kindergarten, the Fueling Brains students outperformed their peers on six of the seven Texas Kindergarten Entry Assessment (TX-KEA) literacy and mathematics subtests. These results suggest that participation in an executive function-focused program, such as Fueling Brains, may help reduce the achievement gap observed at preschool entry between disadvantaged children and their more advantaged peers. This study highlights executive function development as a powerful, evidence-based tool for enhancing early literacy and mathematics skills, particularly for children in underprivileged communities, demonstrating its lasting impact on academic achievement.

IMPORTANCE OF EXECUTIVE FUNCTIONS

Executive function (EF) skills are essential cognitive processes for goal-oriented problem-solving, including working memory, cognitive flexibility, and inhibitory control (Diamond, 2013; Garon et al., 2010).

Working memory helps children retain and connect information, which is crucial for decision-making (Alloway & Alloway, 2013).

Cognitive flexibility allows for switching between tasks and focusing on relevant information (Blair & Raver, 2015).

Inhibitory control enables individuals to suppress distractions and maintain focus on goals (Garon et al., 2010).

These skills help children stay focused longer, make better choices, and prepare for school and future challenges (Diamond, 2013; Zelazo & Carlson, 2020). Early development of EF skills is linked to higher academic achievement and improved social behavior (Ahmed et al., 2019; Diamond, 2013). They are crucial for planning, decision-making, and emotional regulation (Yeager & Yeager, 2013).

Research shows that children who develop these skills early in life are more likely to succeed academically and exhibit prosocial behavior (Blair & Raver, 2015; McClelland et al., 2015). Delays in EF skills can hinder academic and social success, leading to difficulties in task completion and attention (Zelazo & Carlson, 2020). Additionally, a longitudinal study by Moffitt et al. (2011) found that children with lower EF skills had poorer health and reduced life satisfaction in adulthood. The study highlighted that even slight improvements in these skills during childhood can yield significant long-term benefits.

FUELING BRAINS SYSTEM

Fueling Brains is an early childhood education system that focuses on measuring and developing EF skills. Grounded in the science of neuroplasticity and epigenetics, the Fueling Brains system takes a holistic approach focused on optimizing ecologically authentic learning opportunities. It incorporates current research and best practices in education, neuroscience, and technology to provide a systematic approach to increasing the executive capacities of children, mindful of contextual and situational variables that influence development. The system is built on using brain data and resulting iterations of adaptations to inform the growth of children. The program draws on ecologically authentic learning opportunities to foster the generalization of skills developed, combining a hands-on, interactive instructional approach with a creative, community-focused approach. This immersive approach aims to engage the whole child in contextualization. This focus on the whole child and EF develops lifelong skills and abilities so children can be successful both academically and socially (Brock et al., 2009).

RESEARCH PURPOSE AND QUESTION

The purpose of this QED study was to examine the impact of the Fueling Brains executive function-focused program on the reading and mathematics achievement of early childhood students.

The overall research question guiding the investigation was:

Is there a statistically significant mean difference in reading and mathematics achievement between students that participated in an executive function-focused program in comparison to those that participated in a traditional academic-focused early childhood program?

METHOD

Participants were selected from pre-kindergarten (Pre-K) classrooms located in a large economically disadvantaged, high-minority school district in Southeast Texas. In Texas, children are eligible for public Pre-K if they meet certain eligibility criteria, including being economically disadvantaged, homeless, or having a parent in the armed forces.

The participating school district served approximately 24,000 students, with 2,370 enrolled in Pre-K and Kindergarten (Pre-K = 769; Kindergarten = 1,601). School district enrollment was 80.1% minority (16.2% Black, 63.9% Hispanic), which is higher than the State of Texas at 66.3% (12.8% Black, 53.5% Hispanic), and the percentage of students eligible for free and reduced lunch was 71.7%.

During Year 1 of the study, 358 Pre-K students, across 13 schools, were selected to participate in this study. A sample of 179 Pre-K students participating in the Fueling Brains program (treatment group) were individually matched to 179 Pre-K students participating in a traditional academic-focused program (control group) based on gender, race, ethnicity, and at-risk[1] and economically disadvantaged[2] status.

By the end of Pre-K, six students were not available for testing (treatment = 5; control = 1), leaving a total of 352 Pre-K students (treatment = 174; control = 178) for the final analysis (differential attrition = 2.2%). **Table 1** displays the Pre-K student demographics. By the end of their Kindergarten year, 63 students were not available for testing (treatment = 28; control = 35), leaving a total of 289 students (treatment = 146; control = 143) for the final analysis (differential attrition = 3.6%). **Table 2** displays the Kindergarten student demographics.

[1]A student is identified as “at-risk” of dropping out of school using state-defined criteria including inadequate academic progress, limited English proficiency, custody or care of the Department of Protective and Regulatory Services, and/or homeless (TEA, 2020a).

[2]An economically disadvantaged student is identified as one who is eligible for free or reduced-price meals under the U.S. federally mandated National School Lunch and Child Nutrition Program (TEA, 2020b).

TABLE 1 PRE-KINDERGARTEN STUDENT DEMOGRAPHICS (n = 352)

	TREATMENT (%) n = 174	CONTROL (%) n = 178
Male	50.0	51.1
Female	50.0	48.9
African American/Black	24.1	23.0
Asian	1.7	1.7
Caucasian/White	14.4	14.0
Hispanic/Latino	56.9	58.4
2 or more races	2.9	2.8
At-risk	43.7	44.4
Economically disadvantaged	87.4	87.6

TABLE 2 KINDERGARTEN STUDENT DEMOGRAPHICS (n = 289)

	TREATMENT (%) n = 146	CONTROL (%) n = 143
Male	53.4	53.1
Female	46.6	46.9
African American/Black	21.2	21.4
Asian	1.4	2.1
Caucasian/White	13.7	11.0
Hispanic/Latino	60.3	60.7
2 or more races	3.4	3.4
At-risk	43.2	44.8
Economically disadvantaged	87.8	89.0

INSTRUMENTATION

The CIRCLE Progress Monitoring System – PreK (CIRCLE) is a standardized, criterion-referenced measure resulting from a collaborative effort between the U.S. Department of Education, the Texas Education Agency (TEA), and the Children's Learning Institute (CLI) at UTHealth to develop a pre-kindergarten assessment (CLI Engage, 2024). CIRCLE relates well to established standardized tests and is sensitive to growth in children's skills over time (Children's Learning Institute at UTHealth, 2021). The data used to support the reliability and validity of the CIRCLE Progress Monitoring System came from numerous research studies conducted by the CLI over a five-year span. The CIRCLE assessment consists of 9-directly measurable subtests and 6-observable subtests administered at the Beginning-of-Year (BOY, Wave 1), Middle-of-Year (MOY, Wave 2), and End-of-Year (EOY, Wave 3). Data were collected on the subtests measuring rapid letter naming, rapid vocabulary, phonological awareness, and mathematics.

Texas Kindergarten Entry Assessment (TX-KEA) is a standardized, criterion-referenced measure resulting from a collaborative effort between the U.S. Department of Education, the Texas Education Agency, and the Children's Learning Institute (CLI) at UTHealth to develop an assessment to be used to screen children's school readiness upon their entry into kindergarten (CLI Engage, 2025). The TX-KEA consists of 6-domains and 18-subtests with most being administered at BOY, MOY, and EOY. Some of the subtests are teacher reported, while others are student selected. Data were collected on the subtests measuring vocabulary, spelling, letter names, letter sounds, decoding, blending, and mathematics.

DATA COLLECTION & ANALYSIS

Following IRB permission, archived student data were collected from the participating school district for BOY and EOY test scores. Classroom teachers administered BOY assessments to the students prior to any program implementation and the EOY assessments at the end of the academic year. Baseline equivalence for each outcome variable was assessed using BOY/baseline data, adhering to *What Works Clearinghouse* (WWC, 2022) guidelines. Multi-level analysis indicated that unexplained variation was not found to exist across schools.

Therefore, singe-level analyses were utilized to compare the means of the assessment data for the two groups of students. BOY data that met the WWC guidelines for baseline equivalence were analyzed using independent t-tests, while data that did not meet WWC guidelines were analyzed using hierarchical regression analysis. Hierarchical regression analysis allows for statistical adjustments to be made by controlling for baseline data to correct for initial group differences. The significance value was set at .05 and effect sizes calculated using Cohen's *d* and Glass's Δ to quantify the magnitude of differences and the coefficient of determination (r^2) to assess the proportion of variance explained by the program.

RESULTS

YEAR 1: PRE-KINDERGARTEN

Rapid Letter Naming

The results of the independent t-test indicated that there was not a statistically significant mean difference in rapid letter naming subtest scores for students in the treatment group versus those in the control group, $t(350) = .942$, $p = .347$. Although a statistically significant mean difference was not found to exist between the two groups of students, those in the treatment group (M = 21.5, SD = 11.9) on average scored higher in rapid letter naming than those in the control program (M = 19.8, SD = 11.5).

Rapid Vocabulary

The results of the independent t-test indicated that there was a statistically significant mean difference in rapid vocabulary subtest scores for students in the treatment group versus those in the control group, $t(350) = 2.748$, $p = .006$, Cohen's $d = .316$, Glass's $\Delta = .333$, $r^2 = .024$. Students in the treatment group (M = 21.1, SD = 6.3) on average scored higher in rapid vocabulary than those in the control group (M = 19.2, SD = 5.7). The proportion of variation in rapid vocabulary scores attributed to the type of early childhood program was 2.4%.

Phonological Awareness

The results of the hierarchical regression analysis indicated there was a statistically significant mean difference in phonological awareness subtest scores for students in the treatment group versus those in the control group, controlling for BOY scores, $F(1, 349) = 11.42$, $p = .001$, $r^2 = .115$, r^2 change = .032, Cohen's $d = .245$, Glass's $\Delta = .264$. Students in the treatment group (M = 19.1, SD = 6.1) on average scored higher in rapid vocabulary than those in the control group (M = 17.7, SD = 5.3). The proportion of variation in phonological awareness scores attributed to the type of early childhood program was 11.5%.

Mathematics

The results of the independent t-test indicated that there was not a statistically significant mean difference in mathematics subtest scores for students in the treatment group versus those in the control group, $t(350) = 1.207$, $p = .228$. Although a statistically significant mean difference was not found to exist between the two groups of students, those in the treatment group (M = 23.0, SD = 4.4) on average scored higher in mathematics than those in the control group (M = 22.3, SD = 5.9).

RESULTS

YEAR 2: KINDERGARTEN

Vocabulary

The results of the independent t-test indicated that there was not a statistically significant mean difference in vocabulary subtest scores for students in the treatment group versus those in the control group, $t(287) = .497$, $p = .620$. Although a statistically significant mean difference was not found to exist between the two groups of students, those in the treatment group (M = 5.4, SD = 3.1) on average scored higher in vocabulary than those in the control group (M = 5.2, SD = 3.5).

Spelling

The results of the independent t-test indicated that there was a statistically significant mean difference in spelling subtest scores for students in the treatment group versus those in the control group, $t(287) = 2.236$, $p = .026$, Cohen's $d = .266$, Glass's $\Delta = .245$, $r^2 = .017$. Students in the treatment group (M = 19.2, SD = 7.8) on average scored higher in spelling than those in the control group (M = 16.9, SD = 9.4). The proportion of variation in spelling scores attributed to the type of early childhood program was 1.7%.

Letter Names

The results of the hierarchical regression analysis indicated there was a statistically significant mean difference in letter names subtest scores for students in the treatment group versus those in the control group, controlling for BOY scores, $F(1, 286) = 12.19$, $p = .001$, $r^2 = .183$, r^2 change = .034, Cohen's $d = .302$, Glass's $\Delta = .250$. Students in the treatment group (M = 10.4, SD = 1.7) on average scored higher on letter names than those in the control group (M = 9.7, SD = 2.8). The proportion of variation in letter names scores attributed to the type of early childhood program was 18.3%.

Letter Sounds

The results of the hierarchical regression analysis indicated there was a statistically significant mean difference in letter sounds subtest scores for students in the treatment group versus those in the control group, controlling for BOY scores, $F(1, 286) = 7.12$, $p = .008$, $r^2 = .094$, r^2 change = .022, Cohen's $d = .232$, Glass's $\Delta = .217$. Students in the treatment group (M = 6.2, SD = 2.0) on average scored higher on letter sounds than those in the control group (M = 5.7, SD = 2.3). The proportion of variation in letter sounds scores attributed to the type of early childhood program was 9.4%.

YEAR 2: KINDERGARTEN

Decoding

The results of the independent t-test indicated that there was a statistically significant mean difference in decoding subtest scores for students in the treatment group versus those in the control group, $t(287) = 2.018$, $p = .044$, Cohen's $d = .255$, Glass's $\Delta = .261$, $r^2 = .016$. Students in the treatment group (M = 3.2, SD = 2.4) on average scored higher in decoding than those in the control group (M = 2.6, SD = 2.3). The proportion of variation in decoding scores attributed to the type of early childhood program was 1.6%.

Blending

The results of the independent t-test indicated that there was a statistically significant mean difference in blending subtest scores for students in the treatment group versus those in the control group, $t(287) = 3.160$, $p = .002$, Cohen's $d = .356$, Glass's $\Delta = .371$, $r^2 = .031$. Students in the treatment group (M = 6.0, SD = 3.8) on average scored higher in blending than those in the control group (M = 4.7, SD = 3.5). The proportion of variation in blending scores attributed to the type of early childhood program was 3.1%.

Mathematics

The results of the independent t-test indicated that there was a statistically significant mean difference in mathematics subtest scores for students in the treatment group versus those in the control group, $t(287) = 2.942$, $p = .004$, Cohen's $d = .346$, Glass's $\Delta = .333$, $r^2 = .029$. Students in the treatment group (M = 9.2, SD = 3.6) on average scored higher in mathematics than those in the control group (M = 7.9, SD = 3.9). The proportion of variation in mathematics scores attributed to the type of early childhood program was 2.9%.

CONCLUSION

Executive functions are critical cognitive processes that play a fundamental role in childhood development, academic success, and overall life outcomes. The results of this study indicate that an early childhood program emphasizing EF development through guided and open-ended play can significantly enhance young children's literacy and mathematics skills. The results underscore the potential of EF-focused interventions to narrow the achievement gap for economically disadvantaged children, offering a research-based approach to promoting academic success in underprivileged communities. Given these findings, policymakers and educators should consider integrating EF-based strategies into early childhood curricula to foster long-term academic growth and equity in educational outcomes.

REFERENCES

Ahmed, S. P., Bittencourt-Hewitt, A., & Sebastian, C. L. (2019). Neurocognitive bases of emotion regulation development in adolescence. *Developmental Cognitive Neuroscience, 37,* 100-111. https://doi.org/10.1016/j.dcn.2019.100637

Alloway, T. P., & Alloway, R. G. (2013). *The working memory advantage: Train your brain to function stronger, smarter, faster.* Simon and Schuster.

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology, 66*(1), 711-731. https://doi.org/10.1146/annurev-psych-010814-015221

Children's Learning Institute at UTHealth (2021). *CIRCLE progress monitoring user guide 2021-2022.* Retrieved from https://cliengage.org/clirep/CPM/Pre-k/CPM-User-Guide.pdf

CLI Engage (2025). *Texas kindergarten entry assessment.* Retrieved from https://public.cliengage.org/tools/assessment/tx-kea/

CLI Engage (2024). Circle progress monitoring system (prek). Retrieved from https://public.cliengage.org/tools/assessment/circle-progress-monitoring/

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Garon, N., Bryson, S. E., & Smith, I. M. (2010). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 136*(1), 31-60. https://doi.org/10.1037/a0017165

McClelland, M. M., Tominey, S. L., Schmitt, S. A., & Duncan, R. (2015). SEL Interventions in early childhood. *The Future of Children, 27*(1), 33-47. https://doi.org/10.1353/foc.2017.0002

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., ... & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences, 108*(7), 2693-2698. https://doi.org/10.1073/pnas.1010076108

Texas Education Agency. [TEA]. (2020a). *State compensatory education - Expansion of at-risk student definition.* Retrieved from https://tea.texas.gov/about-tea/news-and-multimedia/correspondence/taa-letters/state-compensatory-education-expansion-of-at-risk-student-definition

Texas Education Agency. [TEA]. (2020b). *Profile glossary.* Retrieved from https://tea.texas.gov/texas-schools/accountability/academic-accountability/performance-reporting/2020-profile-glossary.pdf

What Works Clearinghouse [WWC]. (2022). *Procedures and standards handbook, Version 5.0.* Institute of Educational Sciences, U.S. Department of Education, Washington, DC.

Yeager, D. S., & Yeager, J. (2013). *The secrets of self-regulated learning: Strategies for fostering self-motivation and self-discipline in students.* HarperCollins.

Zelazo, P. D., & Carlson, S. M. (2020). The neurodevelopment of executive function skills: Implications for academic achievement gaps. *Psychological Science, 31*(2), 123-137. https://doi.org/10.1177/0956797619890615

Citation: Peters, M., & Brown, A. (2025). *A longitudinal study examining the impact of the Fueling Brains program on pre-kindergarten and kindergarten student achievement.* Houston, Texas: University of Houston-Clear Lake.