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Using Adaptive CAI to Supplement Literacy Development in Early Learners

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This study investigates the impact of using an adaptive computer-assisted instruction (CAI) program in early childhood education. The Waterford Early Reading Program (ERP) is a CAI program that was assigned to kindergarten and first grade students in a school district in Texas for the 2015-2016 school year. The Texas Primary Reading Inventory (TPRI) assessment was administered to students at the beginning, middle, and end of the school year to assess reading skills across multiple strands. Analysis revealed statistically significant higher gains from beginning of year scores to end of year scores for students that used the CAI program, indicating that adaptive computer-assisted instruction can improve early literacy skills more effectively than in-class instruction alone.

INTRODUCTION

There is a well-documented discrepancy in the academic success of students across different racial and ethnic groups (Lee, 2002; National Center for Education Statistics [NCES], 2015). In 2015, African American and Hispanic students scored lower than Caucasian students on the National Assessment of Educational Progress (NAEP) reading scale, in fourth and

eighth grade. By eighth grade, African American students scored twenty-six points lower than Caucasian students, and Hispanic students scored twenty-one points lower than Caucasian students. These trends in NAEP reading scores have not meaningfully changed since 1992 (NCES, 2016). The racial achievement gap can also be seen at the start of a student's educational career, and students as young as four years old have been shown to differ, based on ethnicity, in cognitive abilities such as literacy and reading skills (Wang, 2008). This demonstrates that academic intervention, even at a young age, is important for ensuring all students have equal access to academic opportunity.

On National Assessment of Educational Progress (NAEP) reading scores, the gap between ELL students and native speakers grows from twenty-nine points in fourth grade to thirty-five points in eighth grade. Also by eighth grade, over half of English Language Learner (ELL) students score worse than their native speaking peers on reading measures, with over two-thirds of ELL students scoring Below Basic on reading measures (NCES, 2015). Longitudinal analyses indicate that along different dimensions, such as ELL status (Polat, Zarecky-Hodge, & Schreiber, 2016), and ethnicity (Hemphill & Vanneman, 2011), the achievement gap is expanding. Given this trend, research into effective means of narrowing the achievement gap, along ethnic lines as well as between ELL students and native speakers, at an early stage is necessary and increasingly relevant.

Computer-assisted instruction (CAI) is the presentation of different forms of educational media material in an interactive, instructional way. While teachers conduct large group instruction meant for many students to learn a subject, CAI allows individual students to take control of their learning which increases students' flexibility, interactivity, and engagement (Jethro, Grace, & Thomas, 2012). According to research of CAI in the classroom setting, early childhood instruction using CAI can improve literacy performance (Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2010; Stetter & Hughes, 2010) in comparison to a typical public classroom setting. Technology can customize learning to suit the level and pace for the technology if implemented correctly and if the technology is appropriate for the level of the learner (Jethro, Grace, & Thomas, 2012). Additionally, CAI has been found to increase the enthusiasm for learning in early readers (Flewitt, Messer, & Kucirkova, 2015). CAI presents material with animation and immediate feedback, individualizing the learning process.

Differences in academic achievement and cognitive abilities in the early years lead to a need for technology applications that scaffold, are individualized, and adjust to a child's ability level (Wang, Kinzie, McGuire, & Pan, 2010). This need for individualized educational technology programs

includes programs targeting students of all demographics. In multiple studies, ELL students in elementary school significantly outperformed their control counterparts in early literacy skills when a literacy technology program was paired with regular classroom teaching (Beechler & Williams, 2012; Schechter, Macaruso, Kazakoff, & Brooke, 2015; Tanner & Landon, 2009). Interactive technological curriculum has been found to improve ELL student achievement and close the achievement gap between ELL students and non-ELL students (López, 2010), and interactive technology in education has been found to significantly aid literacy instruction for ELL students (White & Gillard, 2011). However, the use of CAI in the classroom has also been shown to have a limited effect on academic performance in some cases: Students who used supplementary reading software outperformed control students on certain strands of an assessment, while in other strands there was no significant difference in performance between groups (Blachowicz, 2009). Results are not universally positive for students with or at risk of developing reading disabilities, so further investigation is needed into how CAI affects reading comprehension in early learners (Stetter & Hughes, 2010).

The purpose of the present study was to evaluate the effectiveness of the Waterford Early Reading Program in improving early literacy skills of kindergarten and first grade students. This computer-assisted instruction program, we predict, will improve reading scores when incorporated into early elementary school programs.

METHODS

Participants

This study consisted of 3,247 students enrolled in a public school district in Texas during the 2015-2016 school year. Hispanic students made up 39.42% of the population, Caucasian students made up 31.54%, African American students made up 18.02%, Asian students made up 6.93%, students with Two or More Races made up 3.39%, and American Indian/Alaskan Native students and Native Hawaiian/Pacific Islander students accounted for less than 1%.

For kindergarten, the experimental group consisted of 212 students, and the control group consisted of 1,484 students. For first grade, the experimental group consisted of 160 students, and the control group consisted of 1,391 students.

Materials

The Waterford Early Reading Program (ERP)

The program offers a comprehensive computer-adaptive pre-reading and reading curriculum for pre-kindergarten through second grade students. The software presents a wide range of multimedia-based activities in an adaptive sequence tailored to each student's initial placement and his or her individual rate of growth throughout the complete reading curriculum.

The Texas Primary Reading Inventory (TPRI)

The TPRI is an early reading assessment designed to identify the reading development of students in kindergarten through third grade and is administered to students individually. The test identifies students that are at risk for reading difficulties and sets learning objectives for at risk students.

Procedure

The experimental group consisted of students that used ERP throughout the 2015-2016 school year. Kindergarten students were expected to use ERP for fifteen minutes per day, five days per week, and first grade students were expected to use ERP for thirty minutes per day, five days per week. The control group consisted of students who did not use ERP during the 2015-2016 school year. Usage was tracked within the program and monitored weekly by Waterford personnel, and total minutes of usage of ERP for the school year per group was calculated. The TPRI was administered three times throughout the school year, at the beginning, middle, and end of the year.

FINDINGS

Kindergarten

The analysis includes students that participated in the TPRI test at the beginning and at the end of the year. The experimental group for kindergarten (N = 212) consisted of students that used the Waterford Early Read-

ing Program throughout the 2015-2016 school year. The control group (N = 1,484) consisted of students that did not use the Waterford Early Reading Program during the 2015-2016 school year.

Group Differences Using Independent Samples *t*-tests

Independent samples *t*-tests examining gains from beginning of year scores to end of year scores were conducted (Fig. 1 and Fig. 2).

Letter Name Identification

Analysis of gains revealed a significant difference between groups $t(1, 438) = -5.74$, $p < .01$ due to higher gains made by students who used Waterford ($M = 12.03$) than by control students ($M = 5.63$). Effect size ($d = 0.74$).

Letter to Sound Linking

Analysis of gains revealed a significant difference between groups $t(1, 301) = -2.51$, $p < .05$ due to higher gains made by students who used Waterford ($M = 4.63$) than by control students ($M = 2.80$). Effect size ($d = 0.51$).

Inferring Word Meaning

Analysis of gains revealed a significant difference between groups $t(1, 1663) = -4.54$, $p < .01$ due to higher gains made by students who used Waterford ($M = 0.23$) than by control students ($M = 0.05$). Effect size ($d = 0.34$).

Linking Details

Analysis of gains revealed a significant difference between groups $t(1, 1672) = -6.68$, $p < .01$ due to higher gains made by students who used Waterford ($M = 0.11$) than by control students, who decreased in score on average ($M = -0.35$). Effect size ($d = 0.49$).

Recalling Details

Analysis of gains revealed a significant difference between groups $t(1, 1670) = -4.01$, $p < .01$ due to higher gains made by students who used

Waterford (M = 1.58) than by control students (M = 1.36). Effect size (d = 0.30).

Listening Comprehension Total Score

Analysis of gains revealed a significant difference between groups $t(1, 1570) = -7.74$, $p < .01$ due to higher gains made by students who used Waterford (M = 1.96) than by control students (M = 1.07). Effect size (d = 0.58).

Blending Phonemes

Analysis of gains did not reveal a significant difference $t(1, 178) = -0.59$, $p = .556$ between students who used Waterford (M = 3.00) and control students (M = 2.54), but the Waterford students outperformed the control students.

Rhyming

Analysis of gains did not reveal a significant difference $t(1, 474) = 0.02$, $p = .984$ between students who used Waterford (M = 2.18) and control students (M = 2.19).

Blending Word Parts

Analysis of gains did not reveal a significant difference $t(1, 486) = -0.58$, $p = .564$ between students who used Waterford (M = 2.85) and control students (M = 2.71), but the Waterford students outperformed the control students.

Deleting Initial Sounds

Analysis of gains did not reveal a significant difference $t(1, 130) = 0.29$, $p = .772$ between students who used Waterford (M = 2.00) and control students (M = 2.28).

Deleting Final Sounds

Analysis of gains did not reveal a significant difference $t(1, 110) = 0.22$, $p = .826$ between students who used Waterford ($M = 1.75$) and control students ($M = 2.00$).

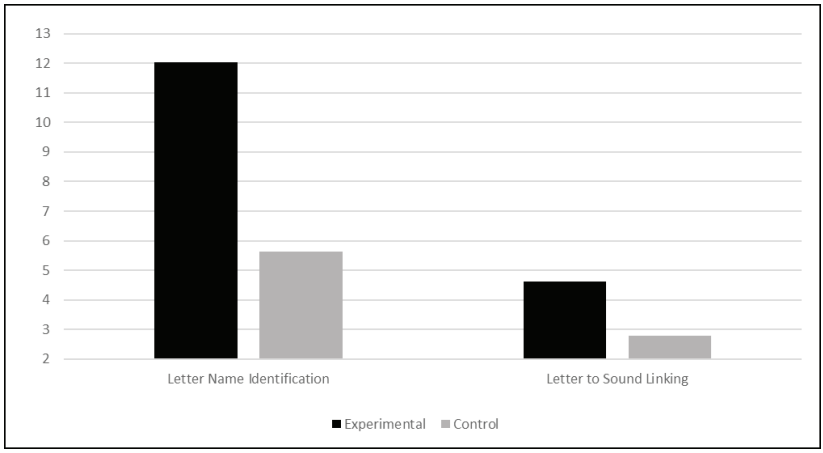

Figure 1. Kindergarten TPRI Gains by Substrand.

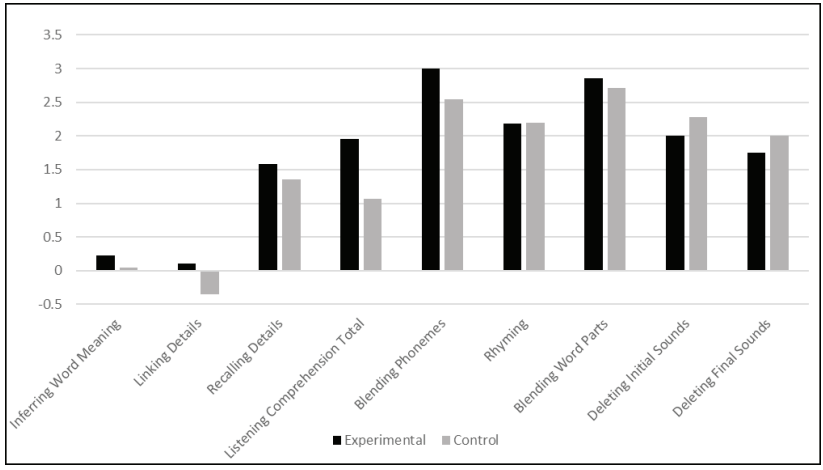

Figure 2. Kindergarten TPRI Gains by Substrand.

Group Differences by Demographics Using Two-Way ANOVAs

Two-way ANOVAs were conducted to examine potential interactions between demographics and Waterford curriculum affecting performance on TPRI substrands (Tab. 1-3).

Letter Name Identification

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Letter Name Identification gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Letter Name Identification gains, $F(1, 436) = 0.00$, $p = .952$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Letter Name Identification gains, $F(1, 436) = 1.84$, $p = .176$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Letter Name Identification gains, $F(5, 428) = 0.95$, $p = .451$. Simple effects analysis showed that African American, Hispanic, and Caucasian students in the experimental group significantly outperformed students in the control group.

Letter to Sound Linking

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Letter to Sound Linking gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Letter to Sound Linking gains, $F(1, 299) = 0.99$, $p = .319$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Letter to Sound Linking gains, $F(1, 299) = 0.08$, $p = .776$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Letter to Sound Linking gains, $F(3, 293) = 0.01$, $p = .998$. Simple effects analysis showed that Hispanic students' gains in the experimental group were higher than in the control group, approaching significance. African American and Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Inferring Word Meaning

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Inferring Word Meaning gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Inferring Word Meaning gains, $F(1, 1661) = 0.23$, $p = .629$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Inferring Word Meaning gains, $F(1, 1661) = 0.72$, $p = .397$. Simple effects analysis showed that LEP students and Non-LEP students in the experimental group significantly outperformed students in the control group.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Inferring Word Meaning gains, $F(5, 1652) = 1.07$, $p = .373$. Simple effects analysis showed that African American and Hispanic students in the experimental group significantly outperformed students in the control group. Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Linking Details

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Linking Details gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Linking Details gains, $F(1, 1670) = 0.82$, $p = .365$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Linking Details gains, $F(1, 1670) = 0.31$, $p = .576$. Simple effects analysis showed that LEP students and Non-LEP students in the experimental group significantly outperformed students in the control group.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Linking Details gains, $F(5, 1661) = 0.44$, $p = .822$. Simple effects analysis showed that African American, Hispanic, and Caucasian students in the experimental group significantly outperformed students in the control group.

Recalling Details

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Recalling Details gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Recalling Details gains, $F(1, 1668) = 0.39$, $p = .534$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Recalling Details gains, $F(1, 1668) = 0.57$, $p = .451$. Simple effects analysis showed that LEP students and Non-LEP students in the experimental group significantly outperformed students in the control group.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Recalling Details gains, $F(5, 1659) = 0.42$, $p = .838$. Simple effects analysis showed that African American and Hispanic students in the experimental group significantly outperformed students in the control group. Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Listening Comprehension Total

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Listening Comprehension Total gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Listening Comprehension Total gains, $F(1, 1568) = 0.92$, $p = .336$. Simple effects analysis showed that for students with no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Listening Comprehension Total gains, $F(1, 1568) = 0.05$, $p = .832$. Simple effects analysis showed that LEP students and Non-LEP students in the experimental group significantly outperformed students in the control group.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Listening Comprehension Total gains, $F(5, 1559) = 0.51$, $p = .766$. Simple effects analysis showed that African American, Hispanic, and Caucasian students in the experimental group significantly outperformed students in the control group.

Table 1

Kindergarten TPRI Gains by Special Education Status

Kindergarten	Active Special Education				No Special Education			
	Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Letter Name Identification	13.0	1.41	6.21	9.85	12.0	8.63	5.60	8.56
Letter to Sound Linking	10.0	.	4.50	3.71	4.42	3.30	2.73	3.62
Inferring Word Meaning	0.13	0.64	-0.15	0.61	0.24	0.65	0.06	0.51
Linking Details	0.25	1.04	0.10	1.05	0.11	1.03	-0.37	0.91
Recalling Details	1.50	0.53	1.45	0.91	1.58	0.83	1.36	0.73
Listening Comprehension Total Score	1.75	1.58	1.40	1.70	1.96	1.56	1.06	1.50

Table 2
Kindergarten TPRI Gains by LEP Status

Kindergarten	LEP				Non-LEP			
	Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Letter Name Identification	6.86	7.98	3.42	7.45	13.30	8.22	6.05	8.77
Letter to Sound Linking	4.67	3.78	2.43	3.54	4.62	3.40	2.89	3.65
Inferring Word Meaning	0.33	0.61	0.08	0.56	0.21	0.66	0.05	0.51
Linking Details	0.43	1.17	0.09	1.06	0.03	0.98	-0.41	0.89
Recalling Details	1.82	0.92	1.53	0.81	1.52	0.78	1.34	0.72
Listening Comprehension Total Score	2.57	1.71	1.70	1.70	1.79	1.48	0.98	1.46

Table 3
Kindergarten TPRI Gains by Ethnicity

Kindergarten	African American				Hispanic				Caucasian			
	Treatment		Control		Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Letter Name Identification	9.73	8.42	4.12	7.38	11.47	8.82	6.73	9.32	14.5	7.92	5.20	7.67
Letter to Sound Linking	4.14	4.34	2.33	3.36	5.00	3.25	3.11	3.72	4.50	3.42	2.67	3.73
Inferring Word Meaning	0.27	0.64	0.03	0.56	0.23	0.65	0.01	0.55	0.21	0.69	0.11	0.45
Linking Details	0.20	0.92	-0.27	0.97	0.14	1.10	-0.23	1.03	-0.04	0.96	-0.53	0.79
Recalling Details	1.77	0.68	1.42	0.72	1.63	0.81	1.42	0.80	1.37	0.88	1.24	0.67
Listening Comprehension Total Score	2.31	1.49	1.17	1.54	2.04	1.65	1.21	1.70	1.55	1.44	0.85	1.30

First Grade

The analysis includes students that participated in the TPRI test at the beginning and at the end of the year. The experimental group for first grade (N = 160) consisted of students that used the Waterford Early Reading Program throughout the 2015-2016 school year. The control group (N = 1,391) consisted of students that did not use the Waterford Early Reading Program during the 2015-2016 school year.

Group Differences Using Independent Samples *t*-tests

Independent samples *t*-tests examining gains from beginning of year scores to end of year scores were conducted (Fig. 3).

Blending Phonemes

Analysis of gains revealed a significant difference between groups $t(1, 138) = -3.79$, $p < .01$ due to higher gains made by students who used Waterford ($M = 1.92$) than by control students ($M = 0.70$). Effect size ($d = 0.85$).

Blending Word Parts

Analysis of gains revealed a significant difference between groups $t(1, 297) = -2.37$, $p < .05$ due to higher gains made by students who used Waterford ($M = 2.00$) than by control students ($M = 1.42$). Effect size ($d = 0.37$).

Blends in Final Position

Analysis of gains revealed a significant difference between groups $t(1, 89) = -2.70$, $p < .01$ due to higher gains made by students who used Waterford ($M = 2.89$) than by control students ($M = 1.64$). Effect size ($d = 0.71$).

Deleting Final Sounds

Analysis of gains did not reveal a significant difference $t(1, 101) = -0.87$, $p = .388$ between students who used Waterford ($M = 2.00$) and control students ($M = 1.57$), but the Waterford students outperformed the control students.

Deleting Initial Sounds

Analysis of gains revealed a significant difference between groups $t(1, 124) = -3.00$, $p < .01$ due to higher gains made by students who used Waterford ($M = 2.17$) than by control students ($M = 0.98$). Effect size ($d = 0.68$).

Final Consonant Substitution

Analysis of gains revealed a significant difference between groups $t(1, 163) = -2.17$, $p < .05$ due to higher gains made by students who used Waterford ($M = 1.25$) than by control students ($M = 0.61$). Effect size ($d = 0.48$).

Initial Blending Substitution

Analysis of gains revealed a significant difference between groups $t(1, 159) = -2.47$, $p < .05$ due to higher gains made by students who used Waterford ($M = 3.04$) than by control students ($M = 2.05$). Effect size ($d = 0.51$).

Initial Consonant Substitution

Analysis of gains revealed a significant difference between groups $t(1, 261) = -2.27$, $p < .05$ due to higher gains made by students who used Waterford ($M = 1.66$) than by control students ($M = 1.04$). Effect size ($d = 0.39$).

Middle Vowel Substitution

Analysis of gains revealed a significant difference between groups $t(1, 137) = -4.01$, $p < .01$ due to higher gains made by students who used Waterford ($M = 1.30$) than by control students ($M = 0.29$). Effect size ($d = 0.97$).

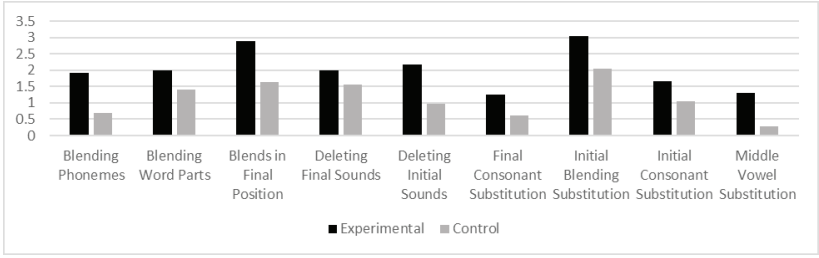

Figure 3. First Grade TPRI Gains by Substrand.

Group Differences by Demographics Using Two-Way ANOVAs

Two-way ANOVAs were conducted to examine potential interactions between demographics and Waterford curriculum affecting performance on TPRI substrands (Tab. 4-6).

Blending Phonemes

Two separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Blending Phonemes gains. There were not enough students with an active special education status that completed the Blending Phonemes strand to analyze special education status.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Blending Phonemes gains, $F(1, 136) = 0.17$, $p = .678$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Blending Phonemes gains, $F(3, 131) = 1.59$, $p = .196$. Simple effects analysis showed that African American and Hispanic students in the experimental group significantly outperformed students in the control group. Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Blending Word Parts

Two separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Blending Word Parts gains. There were not enough students with LEP status that completed the Blending Word Parts strand to analyze LEP status.

There is no significant interaction between the effects of special education status and Waterford curriculum on Blending Word Parts gains, $F(1, 226) = 0.02$, $p = .888$. Simple effects analysis showed that for students with no special education status and students with an active special education status, students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Blending Word Parts gains, $F(3, 289) = 1.25$, $p = .290$. Simple effects analysis showed that African American students in the experimental group significantly outperformed students in the control group. Hispanic and Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Blends in Final Position

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Blends in Final Position gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Blends in Final Position gains, $F(1, 87) = 1.14$, $p = .289$. Simple effects analysis showed that for no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Blends in Final Position gains, $F(1, 87) = 1.11$, $p = .295$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Blends in Final Position gains, $F(3, 82) = 1.49$, $p = .223$. Simple effects analysis showed that African American and Caucasian students in the experimental group significantly outperformed students in the control group. Hispanic students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Deleting Initial Sounds

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Deleting Initial Sounds gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Deleting Initial Sounds gains, $F(1, 122) = 0.04$, $p = .840$. Simple effects analysis showed that for no special education status, students in the experimental group significantly outperformed students in the control group. For students with an active special education status, gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Deleting Initial Sounds gains, $F(1, 122) = 3.12$, $p = .080$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control

group. LEP students' gains in the experimental group were equal to that of the control group.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Deleting Initial Sounds gains, $F(3, 117) = 1.67$, $p = .177$. Simple effects analysis showed that Caucasian students in the experimental group significantly outperformed students in the control group. African American and Hispanic students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Final Consonant Substitution

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Final Consonant Substitution gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Final Consonant Substitution gains, $F(1, 161) = 0.11$, $p = .747$. Simple effects analysis showed that for students with no special education status and students with an active special education status, students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Final Consonant Substitution gains, $F(1, 161) = 0.01$, $p = .939$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Final Consonant Substitution gains, $F(3, 156) = 2.06$, $p = .108$. Simple effects analysis showed that African American students in the experimental group significantly outperformed students in the control group. Hispanic students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Initial Blending Substitution

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Initial Blending Substitution gains.

There was a significant interaction between the effects of special education status and Waterford curriculum on Initial Blending Substitution gains, $F(1, 157) = 4.82$, $p < .05$. Simple effects analysis showed that students with an active special education status in the experimental group significantly outperformed students in the control group. Students with no special education status in the experimental group made slightly higher gains than in the control group, approaching significance.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Initial Blending Substitution gains, $F(1, 157) = 0.11$, $p = .746$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Initial Blending Substitution gains, $F(3, 152) = 2.79$, $p = .043$. Simple effects analysis showed that African American and Caucasian students in the experimental group significantly outperformed students in the control group. Hispanic students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Initial Consonant Substitution

Three separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Initial Consonant Substitution gains.

There was no significant interaction between the effects of special education status and Waterford curriculum on Initial Consonant Substitution gains, $F(1, 138) = 1.73$, $p = .191$. Simple effects analysis showed that for students with no special education status and students with an active special education status, students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Initial Consonant Substitution gains, $F(1, 259) = 0.44$, $p = .506$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Initial Consonant Substitution gains, $F(3, 253) =$

1.02, $p = .383$. Simple effects analysis showed that African American students in the experimental group significantly outperformed students in the control group. Hispanic and Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Middle Vowel Substitution

Two separate ANOVAs were conducted that examined the effects of Waterford curriculum and demographics on Middle Vowel Substitution gains. There were not enough students with an active special education status that completed the Middle Vowel Substitution strand to analyze special education status.

There was no significant interaction between the effects of LEP status and Waterford curriculum on Middle Vowel Substitution gains, $F(1, 135) = 3.31$, $p = .071$. Simple effects analysis showed that Non-LEP students in the experimental group significantly outperformed students in the control group. LEP students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

There was no significant interaction between the effects of ethnicity and Waterford curriculum on Middle Vowel Substitution gains, $F(3, 130) = 1.51$, $p = .216$. Simple effects analysis showed that African American and Hispanic students in the experimental group significantly outperformed students in the control group. Caucasian students' gains in the experimental group were slightly higher than in the control group, but the difference was not significant.

Table 4
First Grade TPRI Gains by Special Education Status

First Grade	Active Special Education				No Special Education			
	Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Blending Word Parts	2.40	1.52	1.92	1.72	2.26	1.60	1.89	1.52
Blends in Final Position	3.50	2.12	0.00	.	2.81	1.87	1.67	1.73
Deleting Initial Sounds	2.00	2.83	0.50	1.00	2.18	1.74	1.00	1.76
Final Consonant Substitution	1.50	1.91	0.60	1.34	1.20	1.74	0.61	1.27
Initial Blending Substitution	5.00	0.00	0.60	0.89	2.89	1.73	2.10	1.97
Initial Consonant Substitution	4.50	0.71	2.29	1.82	2.46	1.69	1.93	1.61

Table 5
First Grade TPRI Gains by LEP Status

First Grade	LEP				Non-LEP			
	Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Blending Phonemes	1.50	2.66	0.50	1.40	2.06	1.80	0.73	1.28
Blends in Final Position	1.40	2.30	0.83	1.64	3.46	1.33	1.80	1.71
Deleting Initial Sounds	1.14	1.21	1.14	1.96	2.59	1.80	0.96	1.71
Final Consonant Substitution	1.25	0.96	0.67	1.59	1.25	1.86	0.60	1.23
Initial Blending Substitution	1.86	1.77	0.94	1.91	3.43	1.60	2.20	1.93
Initial Consonant Substitution	1.33	1.87	1.09	1.62	1.75	1.88	1.04	1.55
Middle Vowel Substitution	0.50	1.00	0.46	1.13	1.50	1.83	0.26	0.87

Table 6
First Grade TPRI Gains by Ethnicity

First Grade	African American				Hispanic				Caucasian			
	Treatment		Control		Treatment		Control		Treatment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Blending Phonemes	3.00	1.58	0.69	1.23	1.87	2.13	0.88	1.53	1.50	2.12	0.44	1.00
Blending Word Parts	2.67	1.56	1.33	1.48	1.79	1.77	1.58	1.66	2.17	1.33	1.29	1.40
Blends in Final Position	4.00	1.41	2.00	1.93	2.30	2.00	2.04	1.65	3.67	1.53	1.11	1.37
Deleting Initial Sounds	2.75	1.50	1.07	1.76	1.80	1.82	1.13	1.99	3.50	1.00	0.76	1.45
Final Consonant Substitution	1.83	2.04	0.14	0.55	1.31	1.80	1.04	1.67	0.00	0.00	0.50	0.89
Initial Blending Substitution	4.40	0.89	2.40	1.82	2.33	1.68	2.28	2.03	4.00	1.41	1.71	2.02
Initial Consonant Substitution	2.00	2.31	0.62	1.18	1.77	1.85	1.47	1.71	1.00	1.41	0.62	1.26
Middle Vowel Substitution	2.25	2.22	0.35	0.77	1.17	1.75	0.41	1.21	1.00	1.00	0.07	0.36

DISCUSSION

Students enter kindergarten with an achievement gap between low- and high-income families, indicating a need for early literacy education that improves student performance (Reardon, 2013). Consistent with previous findings of CAI early reading instruction implementations, the findings of this study suggest that the computer-assisted instruction software was effective in helping participants attain higher levels of reading skills (Saine, et al., 2010; Stetter & Hughes, 2010). Students who used the Waterford Early Reading Program as part of their curriculum consistently outperformed those that did not use ERP. Kindergarten students and first grade students using Waterford outperformed their control counterparts on all strands of the TPRI.

When providing supplemental CAI in a classroom setting, it is important that the software benefits all students. Higher gains throughout the school year were found in LEP students, suggesting that the software is beneficial to non-native English speakers, consistent with previous findings (Beechler & Williams, 2012). These results imply that CAI technology is a beneficial addition to elementary school classrooms, especially in closing the achievement gap between ELL students and non-ELL students (López, 2010). Furthermore, the diversity of the sample emphasizes that the software can lead to positive results in students of different backgrounds: Students with active special education status, LEP students, and students of various ethnicities that used Waterford had higher gains than their control counterparts on all strands of the TPRI. These findings indicate that students that use CAI technology in the classroom will have higher gains in early literacy skills compared to students only taught in a traditional classroom setting.

One suggestion for future research would be to expand the number of participants to a larger sample. While the present study consisted of students across multiple schools, they were within a single school district. Including multiple school districts from different states would provide more generalizable results; additionally, if students were assessed using a standardized test that is used on a national scale, results would be more generalizable. In the future, studies could include longitudinal data to analyze the endurance of gains in literacy skills to strengthen the findings of this study. Overall, CAI is an effective way to provide students with individually paced early literacy instruction to set students on a path to success.

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