

Randomized Control Trial of an Early Learning CAI on Literacy Skills Across Demographic Factors



Haya Shamir, Mikayla Tom, David Pocklington, Alexander Houchins, and Erik Yoder

Abstract This study examined the impact of a targeted computer-assisted instruction (CAI) program on pre-kindergarten literacy skills across demographics, including race/ethnicity, gender, multilingual/monolingual learners, and experience of poverty. A diverse population of students ($N = 2356$) across five U.S. states was randomly assigned to either a CAI reading (experimental) condition or a CAI math and science (control) condition. When assessed following the completion of their respective programs, students in the experimental group outperformed their control counterparts across all subskills assessed. These overall positive literacy outcomes were also mirrored in observations of the demographics considered. The results of this study provide a high-quality contribution to the body of research indicating that usage of CAI can equitably benefit early learners.

1 Introduction and Literature Review

Mastering foundational reading skills at an early age influences academic and professional achievement later in life [1, 2]. Early literacy is a key indicator for later academic success. A student's relative degree of literacy in kindergarten has a larger impact on their fifth-grade performance, in both reading and math, than that student's

H. Shamir (✉) · M. Tom · D. Pocklington · A. Houchins · E. Yoder
Waterford Institute, Taylorsville, UT, USA
e-mail: hayashamir@waterford.org

M. Tom
e-mail: mikaylatom@waterford.org

D. Pocklington
e-mail: davidpocklington@waterford.org

A. Houchins
e-mail: alexanderhouchins@waterford.org

E. Yoder
e-mail: erikyoder@waterford.org

experience of poverty, minority status, or low social skills [1]. Effective early intervention lays down a secure foundation from which students can grow and, importantly, can protect them from starting to fall behind. A meta-analysis reviewing the medium and long-term impacts of early interventions across 22 studies found that participation in early childhood education was associated with improved high school graduation rates and lower placement into special education programs [2]. Identifying areas of concern during this period and interventions that can be effectively utilized during this time are understandably important focuses for new research.

Research has repeatedly demonstrated the negative predictive value of poverty for both academic and professional success. In the United States, a child eligible for a subsidized lunch program from kindergarten to the 8th grade will underperform their more affluent peers by roughly one standard deviation on measures of academic performance [3]. Further, children in families experiencing poverty frequently experience inequitable learning environments where their care givers are unable to fully engage and participate in the child's education [4, 5]. It is the responsibility of both educators and researchers to ensure that this population of vulnerable students has access to the means required for them to achieve their unique academic potential.

Access to comprehensive, high-quality education at an early age can help address these inequities and prime students experiencing poverty for social and academic success. Longitudinal research has indicated that children experiencing poverty who participated in comprehensive pre-kindergarten programs are, by the age of 24, significantly more likely to have full-time employment than individuals who received only traditional kindergarten [6]. Not all interventions are necessarily equally effective; while research indicates that early interventions increase grade retention and ameliorate the need for special education programs, better-funded and targeted programs tend to yield better results than large-scale implementations [7]. New interventions still require critical examination.

Computer-assisted instruction (CAI) is an early education solution that merits further scrutiny. CAI is an educational intervention that leverages the structural advantages of adaptive technology. Lessons are delivered individually and tailored in real-time to individual students. CAI also uses interactive media to hold a student's attention. This approach has been shown to be effective in improving early literacy skills [8]. Research has also indicated that CAI may benefit students experiencing poverty; a meta-analysis examining the efficacy of technologically assisted interventions found strong positive effects on learning outcomes for students experiencing poverty [9].

However, randomized controlled trials (RCT) in this field remain relatively rare. In a recent review of 105 game-based learning studies that fit the inclusion criteria, only 18 were RCTs [10]. RCT designs are the gold standard of research, as they reduce bias and examine cause-and-effect relationships between variables [11].

2 Research Goal

The current quantitative randomized controlled trial was conducted to add to the body of research exploring the benefits of high-quality education, and in particular computer-assisted instruction (CAI), for young students from diverse backgrounds. The aim of this study was to provide educators and policy makers with evidence of the relative efficacy of a CAI intervention, demonstrating both generally positive and equitable literacy outcomes. To that end, the current study evaluated a CAI software curriculum as a learning tool to teach literacy skills to preschool students. It was hypothesized that students randomly assigned to use the reading program would have higher literacy scores than students in the control group.

3 Research Methodology

3.1 *Participants*

The sample for this study ($N = 2356$) consisted of preschool students in Idaho, Wyoming, Montana, North Dakota, and South Dakota in three separate cohorts between 2019 and 2022. Families were contacted by phone and email and invited to participate in the CAI program. Participating students were approximately 5 years old at the time of the posttest.

3.2 *Materials*

Waterford Reading Academy (WRA). WRA is a computer-adaptive instructional program that includes separate reading and math curriculums for early learners. The software utilizes a broad spectrum of educational media in a sequence customized to each student's specific ability and pace of development.

The Waterford Assessment of Core Skills (WACS). WACS is an adaptive assessment designed to assess key pre-literacy and reading skills. The subskills of interest to this study were Blending, Initial Sound, Letter Sound, Letter Recognition, and Listening Comprehension.

3.3 *Procedure*

Three cohorts of preschool students were randomly assigned within each state to experimental and control conditions—students in the experimental group ($n = 1204$)

used the WRA early reading program, while students in the control group ($n = 1152$) used the WRA early math and science program. Students were expected to use the WRA software for fifteen minutes per day, five days per week. While these expectations were not enforced, regular usage was encouraged by contact with families through trained coaches and family liaisons. Families were also instructed on how to make use of the provided hardware and software. Usage was tracked within the program, and the total minutes of usage was calculated. Literacy test scores were analyzed to determine differences between the experimental and control groups. Participants were assessed using WACS prior to and directly following the use of the program, with posttests occurring the summer before students entered kindergarten.

4 Research Outcomes

4.1 Posttest Preschool Group Differences Using Independent Samples *t*-Tests

Independent samples *t*-tests were conducted to examine group differences in WACS end-of-year scores by subskill. (see Fig. 1, Table 1). Overall end-of-year scores were significantly higher for experimental students ($M = 2716.95$) than control students ($M = 2636.10$), $t(2354) = 3.87$, $p < 0.001$. Of the five subskills assessed, students in the experimental group significantly outperformed the control group on Blending, Letter Sound, and Letter Recognition. Scores for Initial Sound and Listening Comprehension made by students in the experimental group were slightly higher than those made by control students, though differences were not significant.

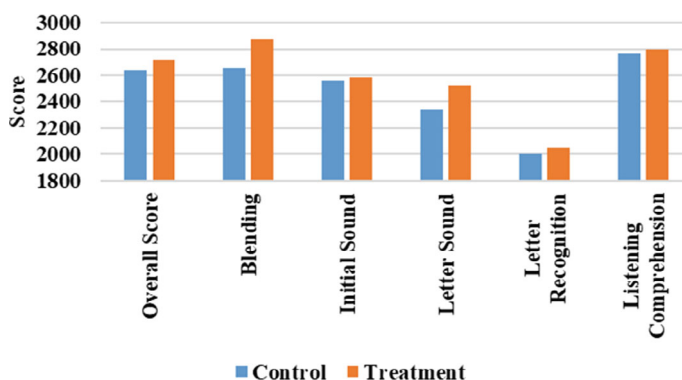


Fig. 1 2019–2022 WACS end-of-year scores by subskill

Table 1 2019–2022 WACS end-of-year overall scores

	Experimental		Control		<i>t</i>	<i>p</i>
	<i>M</i>	<i>N</i>	<i>M</i>	<i>N</i>		
Overall score	2716.95	1204	2636.10	1152	3.87	0.000**
Blending	2876.03	1198	2653.83	1151	7.05	0.000**
Initial sound	2581.38	1201	2558.44	1151	1.52	0.129
Letter sound	2522.21	1201	2339.19	1150	7.43	0.000**
Letter recognition	2050.53	1203	2002.50	1152	5.41	0.000**
Listening comprehension	2793.86	789	2761.94	857	0.49	0.626

p* < 0.05, *p* < 0.01

4.2 Posttest Group Differences Using ANOVAs—Overall Score

Two-way ANOVAs were conducted to examine the effects of WRA and demographics on Overall end-of-year scores (see Fig. 2, Table 2). There were no significant interactions between the effects of WRA and gender, race/ethnicity, multilingual/monolingual, or whether the students were experiencing poverty. Simple effects analysis showed that students in the experimental group significantly outperformed students in the control group for all race/ethnicities and whether they were experiencing poverty. Male and monolingual students in the experimental group significantly outperformed the control group. Female and multilingual learners in the experimental group scored higher than the control group, but the differences were not statistically significant.

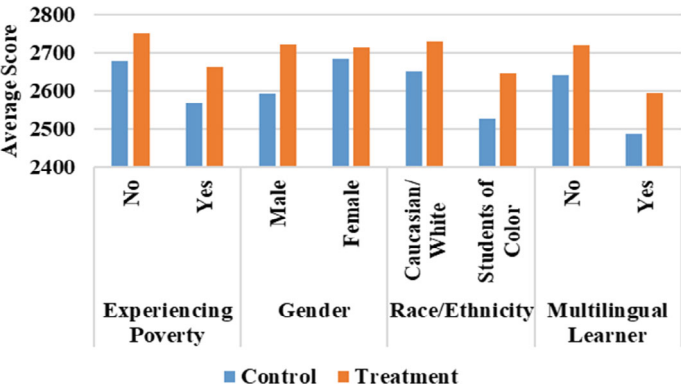


Fig. 2 2019–2022 end-of-year overall scores by demographics

Table 2 2019–2022 end-of-year overall scores by demographics

	Experimental		Control		<i>F</i>	<i>p</i>
	<i>M</i>	<i>N</i>	<i>M</i>	<i>N</i>		
Experiencing poverty					0.31	0.580
No	2750.41	748	2678.55	713		0.007**
Yes	2662.75	454	2567.15	439		0.005**
Gender					2.92	0.054
Male	2722.09	602	2592.87	580		0.000**
Female	2712.18	592	2682.61	563		0.321
Race/ethnicity					0.30	0.740
Caucasian/white	2728.05	1047	2651.81	1006		0.001**
Students of color	2646.43	152	2526.61	143		0.042*
Multilingual learner					0.05	0.828
No	2719.17	1179	2640.91	1116		0.000**
Yes	2594.50	24	2486.81	36		0.420

p* < 0.05, *p* < 0.01

4.3 Posttest Group Differences Using ANOVAs

Blending. Two-way ANOVAs were conducted to examine the effects of WRA and demographics on end-of-year Blending scores (see Fig. 3, Table 3). There were no significant interactions between the effects of WRA and gender, race/ethnicity, multilingual/monolingual, or whether the students were experiencing poverty. Simple effects analysis showed that students in the experimental group significantly outperformed the control group across gender, race/ethnicity, multilingual/monolingual, and whether they were experiencing poverty.

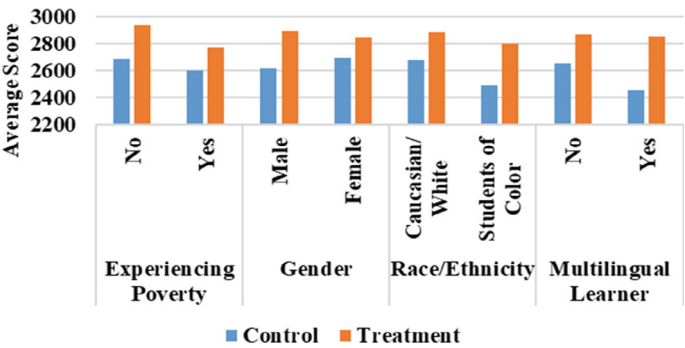


Fig. 3 2019–2022 end-of-year blending scores by demographics

Table 3 2019–2022 end-of-year blending scores by demographics

	Experimental		Control		<i>F</i>	<i>p</i>
	<i>M</i>	<i>N</i>	<i>M</i>	<i>N</i>		
Experiencing poverty					1.70	0.192
No	2939.89	745	2685.67	713		0.000**
Yes	2771.76	451	2602.00	438		0.001**
Gender					1.94	0.145
Male	2899.35	598	2620.44	580		0.000**
Female	2853.01	590	2692.30	562		0.000**
Race/ethnicity					0.49	0.612
Caucasian/white	2887.39	1041	2676.36	1005		0.000**
Students of color	2801.91	152	2496.98	143		0.001**
Multilingual learner					0.83	0.362
No	2876.09	1173	2660.31	1115		0.000**
Yes	2854.67	24	2453.17	36		0.046*

* $p < 0.05$, ** $p < 0.01$

Letter Sound. Two-way ANOVAs were conducted to examine the effects of WRA and demographics on end-of-year Letter Sound scores (see Fig. 4, Table 4). There were no significant interactions between the effects of WRA and gender, race/ethnicity, multilingual/monolingual or whether the students were experiencing poverty. Simple effects analysis showed that students in the experimental group significantly outperformed the control group across gender, race/ethnicity, and whether they were experiencing poverty. Monolingual students in the experimental group significantly outperformed the control group. Multilingual learners in the experimental group scored higher than the control group, but the difference was not statistically significant.

Letter Recognition. Two-way ANOVAs were conducted to examine the effects of CAI and demographics on end-of-year Letter Recognition scores (see Fig. 5, Table 5). There were no significant interactions between the effects of WRA and gender, race/ethnicity, multilingual/monolingual, or whether the students were experiencing poverty. There was a significant interaction between the effects of WRA and gender. Simple effects analysis showed that students in the experimental group significantly outperformed students in the control group who were and were not experiencing poverty. Male, Caucasian/White, and monolingual students in the experimental group significantly outperformed the control group. Female students and students of color in the experimental group scored higher than the control group, but the differences were not statistically significant.

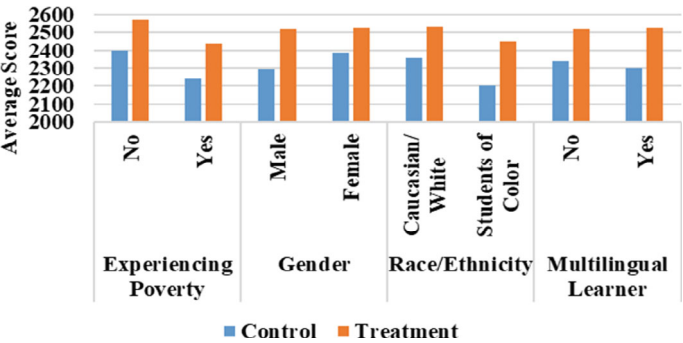


Fig. 4 2019–2022 end-of-year letter sound scores by demographics

Table 4 2019–2022 end-of-year letter sound scores by demographics

	Experimental		Control		F	p
	M	N	M	N		
Experiencing poverty					0.30	0.583
No	2571.15	746	2399.22	712		0.000**
Yes	2441.23	453	2241.62	438		0.000**
Gender					1.74	0.183
Male	2521.35	599	2293.74	579		0.000**
Female	2524.34	592	2385.38	562		0.000**
Race/ethnicity					0.66	0.519
Caucasian/white	2532.60	1044	2358.02	1004		0.000**
Students of color	2452.76	152	2203.27	143		0.000**
Multilingual learner					0.07	0.791
No	2522.03	1176	2340.37	1114		0.000**
Yes	2526.75	24	2302.86	36		0.155

* $p < 0.05$, ** $p < 0.01$

5 Discussion

The results of this study are consistent with previous findings that WRA can improve the literacy skills of young learners [8]. Students who were randomly assigned to the WRA reading software achieved significantly higher overall scores on the end-of-year literacy assessment compared to their control group counterparts. The experimental group also exhibited higher scores than the control group across all subskills of the assessment.

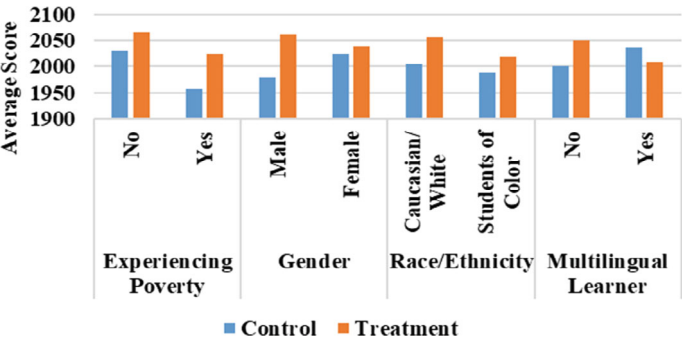


Fig. 5 2019–2022 end-of-year letter recognition scores by demographics

Table 5 2019–2022 end-of-year letter recognition scores by demographics

	Experimental		Control		<i>F</i>	<i>p</i>
	<i>M</i>	<i>N</i>	<i>M</i>	<i>N</i>		
Experiencing poverty					2.67	0.103
No	2066.26	747	2029.91	713		0.001**
Yes	2023.98	454	1957.99	439		0.000**
Gender					7.82	0.000**
Male	2061.80	601	1979.58	580		0.000**
Female	2039.47	592	2024.76	563		0.244
Race/ethnicity					2.36	0.095
Caucasian/white	2055.71	1046	2003.82	1006		0.000**
Students of color	2018.87	152	1989.19	143		0.236
Multilingual learner					1.81	0.179
No	2051.20	1178	2001.40	1116		0.000**
Yes	2009.08	24	2036.50	36		0.629

p* < 0.05, *p* < 0.01

6 Conclusions

Additionally, students in the experimental group achieved higher overall scores than the control group across demographics including gender, race/ethnicity, multilingual/monolingual, and whether they were experiencing poverty. Notably, when examining results for students experiencing poverty, no interactions were found for any subskill. These results meaningfully demonstrate that all students can benefit from the use of WRA at a young age, which can be especially impactful for students experiencing poverty who are at risk of falling behind early in their academic careers [3]. This

study contributes to the need for rigorous RCT designs in education research to inform educators and policymakers about high-quality instruction backed by evidence.

Through critically examining the efficacy of an early literacy intervention, this study identifies a method which can help young learners master essential foundational literacy skills. Appropriately applied, this program can ensure students move forward in their education and lives prepared for success.

7 Future Steps

It is appropriate to briefly acknowledge some limitations of the current study. In examining race/ethnicity, this study aggregated students of color into a single category due to the sample sizes of the individual groups. While the intention was to ensure that all students in the sample were considered, this does potentially obscure differences between groups and fall afoul of the problematic ‘Caucasian as baseline’ trope. Future research could examine the effect of the program in more granular and specific terms. Additionally, while the multi-cohort design provides a robust view of students at five years old across multiple years, it does not assess longitudinal data and future research may benefit from including this analysis.

References

1. Cooper, B.R., Moore, J.E., Powers, C.J., Cleveland, M., Greenberg, M.T.: Patterns of early reading and social skills associated with academic success in elementary school. *Early Educ. Dev.* **25**(8), 1248–1264 (2014)
2. McCoy, D.C., Yoshikawa, H., Ziol-Guest, K.M., Duncan, G.J., Schindler, H.S., Magnuson, K., Shonkoff, J.P.: Impacts of early childhood education on medium-and long-term educational outcomes. *Educ. Researcher* **46**(8), 474–487 (2017)
3. Micheltmore, K., Dynarski, S.: The gap within the gap: using longitudinal data to understand income differences in educational outcomes. *AERA Open* **3**(1) (2017)
4. Arce, S.: Exploring parent and teacher perceptions of family engagement. *Int. J. Teach. Leadersh.* **10**(2), 82–94 (2019)
5. Poon, K.: The impact of socioeconomic status on parental factors in promoting academic achievement in Chinese children. *Int. J. Educ. Dev.* **75**, 102175 (2020)
6. Reynolds, A.J., Temple, J.A., Ou, S.R., Robertson, D.L., Mersky, J.P., Topitzes, J.W., Niles, M.D.: Effects of a school-based, early childhood intervention on adult health and well-being: a 19-year follow-up of low-income families. *Arch. Pediatr. Adolesc. Med.* **161**(8), 730–739 (2007)
7. Barnett, W.S.: Long-term effects of early childhood programs on cognitive and school outcomes. *Future Child.* 25–50 (1995)
8. Booton, S.A., Hodgkiss, A., Murphy, V.A.: The impact of mobile application features on children’s language and literacy learning: a systematic review. *Comput. Assist. Lang. Learn.* 1–30 (2021)
9. López-Escribano, C., Valverde-Montesino, S., García-Ortega, V.: The impact of e-book reading on young children’s emergent literacy skills: an analytical review. *Int. J. Environ. Res. Public Health* **18**(12), 6510 (2021)

10. Hainey, T., Connolly, T.M., Boyle, E.A., Wilson, A., Razak, A.: A systematic literature review of games-based learning empirical evidence in primary education. *Comput. Educ.* **102**, 202–223 (2016)
11. Hariton, E., Locascio, J.J.: Randomized controlled trials—the gold standard for effectiveness research: study design: randomized controlled trials. *BJOG: Int. J. Obstet. Gynaecol.* **125**(13), 1716 (2018)