

USAGE MATTERS: LONGITUDINAL BENEFITS OF COMPUTER-ASSISTED INSTRUCTION FOR EARLY LEARNERS

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Abstract

Prior research has indicated the importance of high-quality early intervention for young learners but has yet to address the question of relative usage. This longitudinal study followed two cohorts of kindergarten students in sequential years within a single school district who received Waterford Reading Academy (WRA), a computer adaptive instruction program, to teach early literacy skills. Within each cohort, students were grouped by their relative usage in kindergarten, comparing high usage (at least 1,000 minutes) to low usage (less than 500 minutes). Student outcome measures were assessed at the end of first grade, one year after the use of the program had ceased. Analysis indicated that students who used the program saw sustained benefits from the program, with comparable results across both cohorts assessed. Analysis was further parsed in demographic terms, including race/ethnicity, special education services, students experiencing poverty, and multi-lingual learner status. Broadly speaking, across all groups assessed, students with more use of the program outperformed comparison students with lower use.

Keywords: Computer-assisted Instruction, Early Childhood Education, Fidelity of Usage, Early Literacy

1 INTRODUCTION

Research has demonstrated that high-quality early childhood education can have a lasting positive impact on students and is associated with higher rates of high school graduation and a decrease in grade retention [1, 2]. In particular, developing literacy skills early has been found to relate to academic success in later grades. When students are below grade level in achieving literacy, supplementary instruction and interventions at an early age can help them attain the skills they need. In a study across 55 schools, kindergarten through second grade students randomly assigned to receive a literacy intervention achieved up to 25% higher reading outcomes than students who did not receive the intervention [3].

However, not all students are able to receive quality instruction at a young age, putting them at a disadvantage academically [4]. Families experiencing poverty may not have the means to live in an area with access to preschool or full-day kindergarten. Even when families who live areas with fewer resources have access to preschool, the quality of education provided may not be adequate. These opportunities can come at the cost of time and money, and lower-income families are not able to spend the same resources on their children's education compared with higher income families [5]. The result is an academic achievement gap between students experiencing and not experiencing poverty, as students not experiencing poverty are given more instructional support at a young age. Early literacy interventions may help bridge this achievement gap by providing students experiencing poverty with high-quality, individualized instruction [6, 7]. One method to facilitate this would be through the use of technology.

Computer-assisted instruction (CAI) uses technology to provide multi-media educational software to students at an individual level [8]. As students progress through content, the software measures their mastery of concepts within the curriculum. It determines which lessons they should receive next to best reinforce concepts with which they need support. Not only can this provide students with efficient lesson paths to spend the most time where they need the most help, but it also provides students with immediate feedback on their progress across different learning objectives. This feedback, in turn, allows educators to better understand where their students are struggling and where they should focus their efforts to address the learning needs of their classrooms.

The use of CAI has generally been shown to be beneficial. A synthesis of 20 high-quality meta-analyses found that studies investigating the use of technology to assist classroom instruction resulted in a small average effect size of $g = 0.29$ [9]. Research has also demonstrated the benefits of CAI for early childhood education in particular; Another meta-analysis of over 50 studies of early literacy interventions involving instruction through the use of computers found positive effects for students in preschool and kindergarten [10]. Research has also shown that using CAI to teach students literacy

skills can be especially beneficial for lower-performing students, providing targeted instruction to help bridge gaps in their understanding of key concepts, thereby allowing them to catch up to their peers [11, 12].

Although CAI can be used as a tool to close achievement gaps between lower-performing and higher-performing students, the degree to which students can spend time using CAI software also plays a role in how impactful the instruction will be. A second-order meta-analysis of studies related to CAI found that learning outcomes had a positive, strong association with the fidelity of the CAI implementation, the degree to which educators had access to training and support, and the amount of enthusiasm exhibited by the students [13]. This indicates that positive outcomes were most pronounced when students were engaged and using the software to fidelity, while students who did not use CAI for the recommended amount of time showed little to no improvements in their learning outcomes.

A recent study of kindergarten students found a positive dosage effect for the use of CAI; growth in literacy skills from the beginning to the end of the school year was compared between students assigned to use CAI software and students who were not. Results found significant differences between groups only when including students with high software usage [14]. Other studies, however, have found mixed results for students using software to learn, concluding that the amount of time spent using CAI had little to no effect, or even a negative effect, on student learning [15, 16]. Because of these mixed results, further research is needed to determine the impact of CAI on fidelity.

In the current study, literacy scores were compared for first-grade students who spent either a high or low amount of time using a computer-adaptive reading program during their kindergarten school year. It was hypothesized that students who had higher usage of CAI software, when assessed one year after using it, would have higher literacy assessment scores than students who had low usage of CAI, demonstrating a long-term effect of CAI on literacy scores.

2 METHODOLOGY

2.1 Participants

The sample for this study ($N = 1,368$) consisted of first-grade students in a school district in Texas during the 2020-2021 and 2021-2022 school years. The sample was 52% female, 52% from households experiencing poverty, 5% multi-lingual learner, 55% Latino/a and 38% Caucasian/White.

2.2 Measures

2.2.1 *Waterford Reading Academy (WRA)*

Waterford Reading Academy (WRA) is a computer-adaptive reading curriculum 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.

2.2.2 *Texas Primary Reading Inventory (TPRI)*

A standardized diagnostic reading assessment for students in kindergarten through third grade. This assessment has been shown to be both valid and reliable [17].

2.3 Procedure

Students were separated into experimental and control groups based on their total time spent using WRA during the previous school year when they were in kindergarten. For the 2020-2021 cohort, students with at least 1,000 minutes during kindergarten in 2019-2020 were included in the experimental group ($n = 534$), while students with less than 500 minutes were included in the control group ($n = 115$). For the 2021-2022 cohort, students with at least 1,000 minutes during kindergarten in 2020-2021 were included in the experimental group ($n = 592$), while students with less than 500 minutes were included in the control group ($n = 127$).

The TPRI literacy assessment was administered to students in each cohort at the end of their school year in first grade.

3 RESULTS

3.1 2020-2021 Group Differences Using Independent Samples *t*-tests

Independent samples *t*-tests were conducted to examine group differences in end-of-first-grade scores between experimental and control groups (see Fig. 1). Analysis of end-of-first-grade Word Reading scores revealed a significant difference between groups, $t(1, 152) = -3.64, p < .001$, due to higher end-of-first-grade scores made by experimental students ($M = 8.00$) than by control students ($M = 6.41$). Effect size ($d = 0.59$).

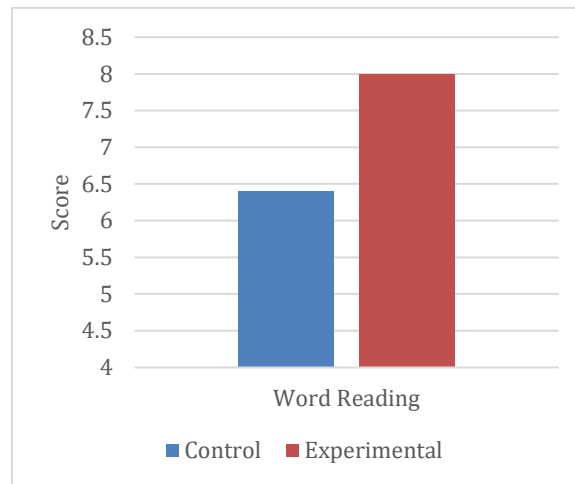


Figure 1. 2020-2021 end-of-first-grade TPRI Word Reading scores.

3.2 2020-2021 Group Differences Using ANOVAs

Three separate two-way ANOVAs were conducted to examine the long-term effects of WRA and demographics on end-of-first-grade Word Reading scores (see Fig. 2).

3.2.1 Race/Ethnicity

Analysis revealed no significant interaction between the effects of race/ethnicity and usage of WRA, $F(4, 639) = 1.50, p = .202$. Simple effects analysis indicated that for Latino/a students, scores in the experimental group were significantly higher than in the control group. Scores for Caucasian/White students in the experimental group were slightly higher than in the control group, but the difference was not significant.

3.2.2 Special Education Services

Analysis revealed no significant interaction between the effects of special education services and usage of WRA, $F(1, 645) = 1.49, p = .222$. Simple effects analysis indicated that for students without special education services, scores in the experimental group were significantly higher than in the control group. Scores for students with special education services in the experimental group were slightly higher than in the control group, but the difference was not significant.

3.2.3 Experiencing Poverty

Analysis revealed no significant interaction between the effects of experiencing poverty and usage of WRA, $F(1, 645) = 0.18, p = .669$. Simple effects analysis indicated that for students from families experiencing poverty, scores in the experimental group were significantly higher than in the control group. Scores for students from families not experiencing poverty in the experimental group were slightly higher than in the control group, but the difference was not significant.

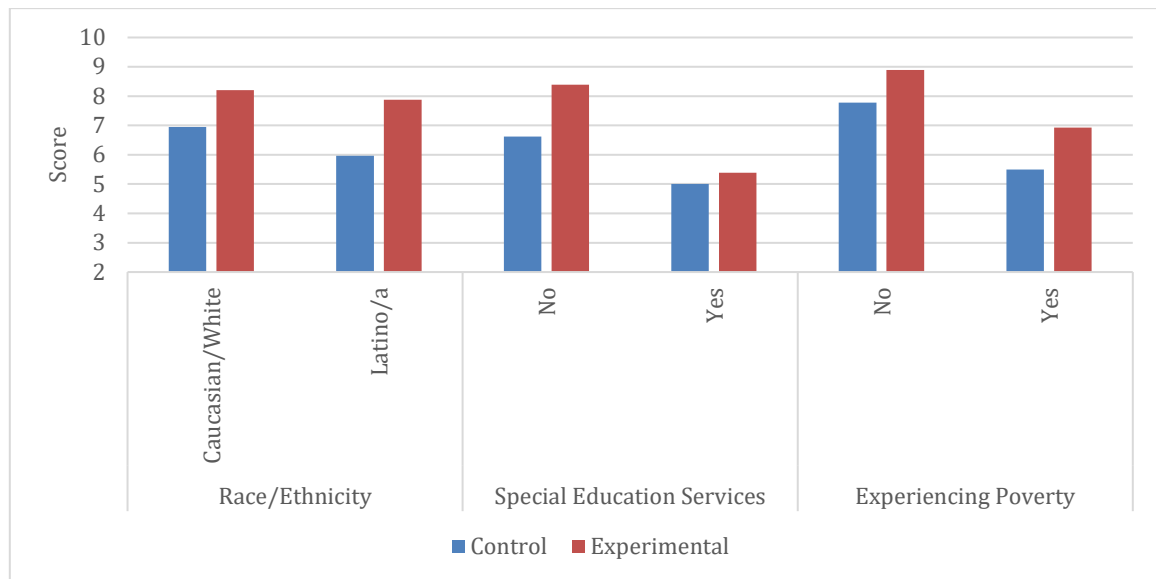


Figure 2: 2020-2021 end-of-first-grade TPRI Word Reading scores by demographics.

3.3 2021-2022 Group Differences Using Independent Samples *t*-tests

Independent samples *t*-tests were conducted to examine group differences in end-of-first-grade scores between experimental and control groups (see Fig. 3). Analysis of end-of-first-grade Word Reading scores revealed a significant difference between groups, $t(1, 170) = -4.20, p < .001$, due to higher end-of-first-grade scores made by experimental students ($M = 8.22$) than by control students ($M = 6.48$). Effect size ($d = 0.65$).

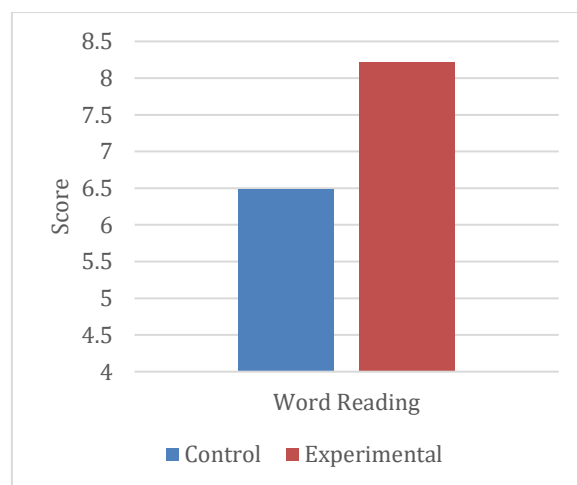


Figure 3: 2021-2022 end-of-first-grade TPRI Word Reading scores.

3.4 2021-2022 Group Differences Using ANOVAs

Four separate two-way ANOVAs were conducted to examine the long-term effects of WRA and demographics on end-of-first-grade Word Reading scores (see Fig. 4).

3.4.1 Race/Ethnicity

Analysis revealed no significant interaction between the effects of race/ethnicity and usage of WRA, $F(3, 708) = 1.63, p = .182$. Simple effects analysis indicated that for Latino/a students, scores in the experimental group were significantly higher than in the control group. Scores for African American/Black and Caucasian/White students in the experimental group were slightly higher than in the control group, but the difference was not significant.

3.4.2 Special Education Services

Analysis revealed no significant interaction between the effects of special education services and usage of WRA, $F(1, 714) = 2.31, p = .129$. Simple effects analysis indicated that for students with and without special education services, scores in the experimental group were significantly higher than in the control group.

3.4.3 Experiencing Poverty

Analysis revealed no significant interaction between the effects of experiencing poverty and usage of WRA, $F(1, 714) = 2.95, p = .086$. Simple effects analysis indicated that for students from families experiencing poverty, scores in the experimental group were significantly higher than in the control group. Scores for students from families not experiencing poverty in the experimental group were slightly higher than in the control group, but the difference was not significant.

3.4.4 Multi-Lingual Learner Status

Analysis revealed no significant interaction between the effects of multi-lingual learner status and usage of WRA, $F(1, 714) = 0.41, p = .522$. Simple effects analysis indicated that for students with no multi-lingual learner status, scores in the experimental group were significantly higher than in the control group. Scores for students with multi-lingual learner status in the experimental group were slightly higher than in the control group, but the difference was not significant.

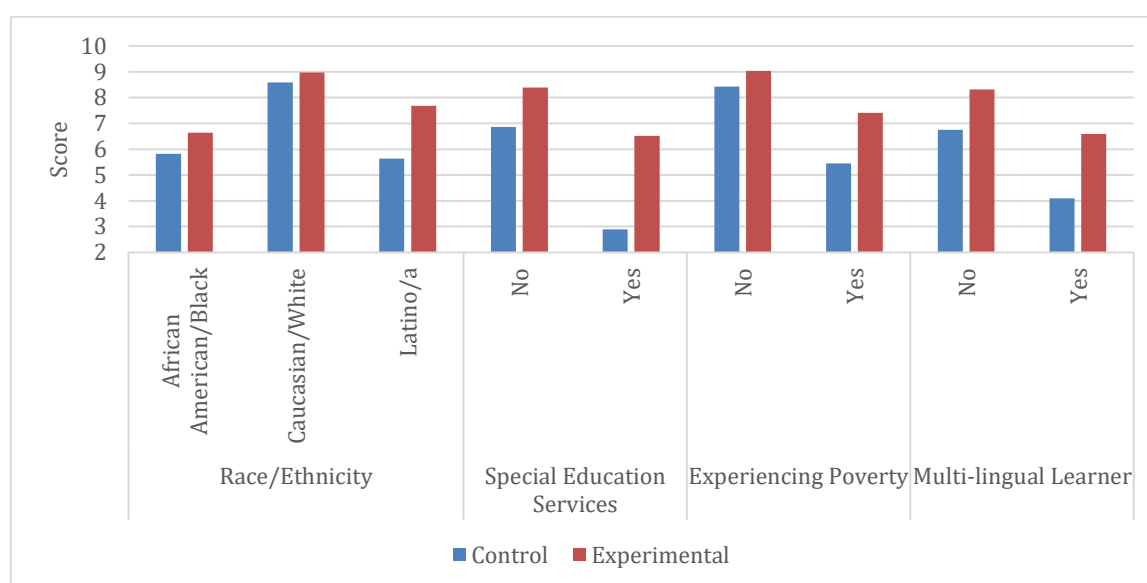


Figure 4: 2021-2022 end-of-first-grade TPRI Word Reading scores by demographics.

3.5 Combined Group Differences Using Independent Samples *t*-tests

Independent samples *t*-tests were conducted to examine group differences in end-of-first-grade scores between experimental and control groups (see Fig. 5). Analysis of end-of-first-grade Word Reading scores revealed a significant difference between groups, $t(1, 323) = -5.56, p < .001$, due to higher end-of-first-grade scores made by experimental students ($M = 8.11$) than by control students ($M = 6.45$). Effect size ($d = 0.62$).

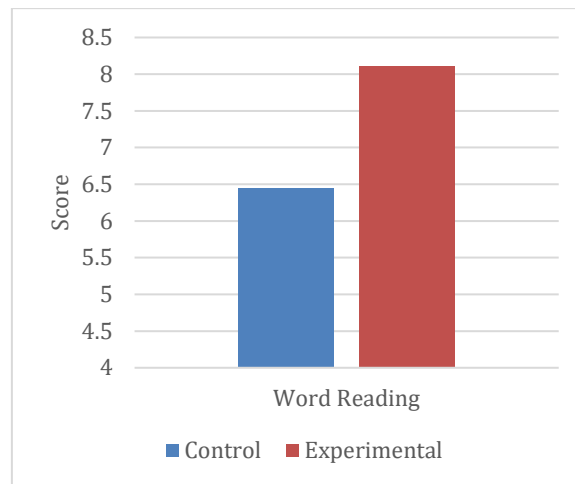


Figure 5: Combined end-of-first-grade TPRI Word Reading scores.

3.6 Combined Group Differences Using ANOVAs

Four separate two-way ANOVAs were conducted to examine the long-term effects of WRA and demographics on end-of-first-grade Word Reading scores (see Fig. 6).

3.6.1 Race/Ethnicity

Analysis revealed no significant interaction between the effects of race/ethnicity and usage of WRA, $F(4, 1356) = 1.91, p = .106$. Simple effects analysis indicated that for Latino/a students, scores in the experimental group were significantly higher than in the control group. Scores for Caucasian/White students in the experimental group were slightly higher than in the control group, but the difference was not significant.

3.6.2 Special Education Services

Analysis revealed no significant interaction between the effects of special education services and usage of WRA, $F(1, 1363) = 0.01, p = .932$. Simple effects analysis indicated that for students with and without special education services, scores in the experimental group were significantly higher than in the control group.

3.6.3 Experiencing Poverty

Analysis revealed no significant interaction between the effects of experiencing poverty and usage of WRA, $F(1, 1363) = 2.40, p = .122$. Simple effects analysis indicated that for students from families experiencing poverty and not experiencing poverty, scores in the experimental group were significantly higher than in the control group.

3.6.4 Multi-Lingual Learner Status

Analysis revealed no significant interaction between the effects of multi-lingual learner status and usage of WRA, $F(1, 1363) = 0.52, p = .471$. Simple effects analysis indicated that for students with no multi-lingual learner status and students with multi-lingual learner status, scores in the experimental group were significantly higher than in the control group.

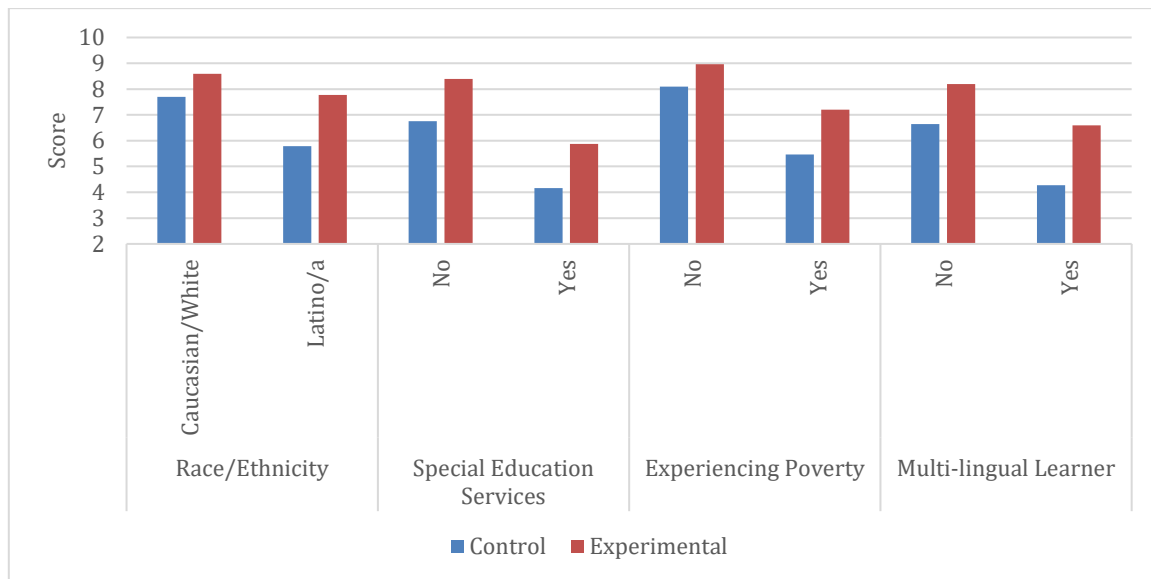


Figure 6: Combined end-of-first-grade TPRI Word Reading scores by demographics.

4 CONCLUSIONS

It was hypothesized that when both cohorts of students were assessed a year after using WRA, students with higher use of the program would have higher scores than their comparison counterparts. When assessed at the end of first grade, students in both cohorts who used WRA for at least 1,000 minutes while in kindergarten significantly outperformed their comparison counterparts who used WRA for less than 500 minutes. Up to a year after use of WRA had ceased, the benefit from the relative use of the program was evident. The impact of the program was comparable across both cohorts, with effect sizes for each in the medium range, indicating that benefits associated with higher use of the program were both substantive and stable from year to year. This finding expands on prior research into the lasting efficacy of CAI.

For all demographics assessed, students with higher use of WRA consistently outperformed their comparison peers. All students that used the program to fidelity across all available demographics, including race/ethnicity, special education services, experiencing poverty, and multi-lingual learner status, benefited from the use of the program at the end of first grade. This finding points to CAI as a viable tool with a lasting and equitable impact on the educational outcomes of all young learners.

Some limitations of the current study should be acknowledged briefly. This study only followed up on student performance a year after using the intervention. While it demonstrates that the benefits of using the program to fidelity persist into first grade, its ability to infer the effect of the computer-adaptive program after that point is limited. The study also occurred within a single school district and was possibly subject to local factors that may have inadvertently affected outcomes.

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