Can CAI Improve Literacy and Mathematics Achievement in Young Low Socioeconomic Status Students?

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Abstract: This study explored the effectiveness of the Waterford Early Reading Program (ERP) and the Waterford Early Math and Science Program (EMS), comprehensive computer-adaptive programs, for teaching early reading concepts to kindergarten and first grade students from low socioeconomic (SES) backgrounds. Students attended two different districts in South Carolina and Indiana during the 2015-2016 school year; the experimental groups used the CAI program, and the control groups either had low usage of the CAI program or did not use the CAI program. Analyses revealed the low-SES students in the experimental group outperformed students in the control group on multiple reading and math assessments, indicating that the use of a CAI program such as ERP or EMS in addition to the traditional classroom setting could significantly improve reading and math skills of students from differing low socioeconomic backgrounds.

Introduction

Students enter elementary school with differences in cognitive and academic skills due to socioeconomic differences which have been found to exacerbate in school, a term called the achievement gap (Crosnoe, Leventhal, Wirth, Pierce, & Pianta, 2010). Socioeconomic status (SES) includes family income, parental education, and environment, all of which combine to impact the school readiness of students (Janus & Duku, 2007). There is a positive relationship between SES and academic achievement, with research showing that the achievement gap between students of differing SES widens after elementary school if not addressed (Caro, 2009). Students from low-SES homes do not enter school with the English language skills required to succeed academically because low-SES parents tend to use a more freeform vocabulary (Hoff, 2013).

The Coleman Report of 1966 documented that the differences in educational performance were largely impacted by socioeconomic conditions, creating inspiration for new research on closing the achievement gap between students (Rassouli-Currier, 2011). Over the past fifty years, the income gap in the United States has grown, paralleling the achievement gap between low- and high-SES students (Schwartz, 2014). Effective early intervention addresses the achievement gap and improves the school readiness of low-SES students, yet in 2012 on average only 46% of three- to six-year-olds from low-income families compared to 72% of three- to six-year-olds from high-income families were enrolled in preschool (Child Trends Databank, 2014). High-quality early education was shown to greatly improve the academic outcomes of economically disadvantaged children, but if the educational system expands the gap between low- and high-SES students, then that system needs to be reformed to address the individual needs of all young learners.

Computer-assisted instruction (CAI) is a computerized educational software that allows for individualized instruction and feedback (Jacob, Berger, Hart, & Loeb, 2016). When used effectively as a supplemental tool in the

classroom, CAI technology has been found to increase the effectiveness of school education (Thai & Ponciano, 2016). For example, low-SES preschool students using CAI technology before entering kindergarten were found to have improved literacy and math skills, showing the strongest improvement in test scores compared to students not using the technology (McManis & McManis, 2016). Emerging technologies can reach students across the country, however, use of technology does not guarantee improved education (Jacob, et al., 2016). Since students from low-SES families enter elementary school, on average, with less-advanced academic and behavioral skills, CAI curriculum may close the achievement gap between students from families of low-SES backgrounds.

Methods

Participants

Participants were enrolled in kindergarten and first grade classes across two different school districts in South Carolina and Indiana. The majority of students in both districts are Caucasian, and approximately one-third of the first district and one-half of the second district qualified for free lunch.

The first district consisted of 2,148 students enrolled in a public school district in South Carolina during the 2015-2016 school year. For kindergarten and first grade, the experimental groups consisted of 1,004 and 1,064 students respectively, and the control groups consisted of 28 and 52 students respectively. Students in the experimental groups used Waterford curriculum for more than 1,000 minutes, and students in the control groups used the curriculum for less than 500 minutes.

The second district consisted of 451 students enrolled in a public school district in Indiana during the 2014-2015 (control) and 2015-2016 (experimental) school years. For the Waterford Early Reading Program (ERP), the experimental group for kindergarten consisted of 108 students, and the control group consisted of 30 students. For the Waterford Early Math and Science Program (EMS), the experimental groups for kindergarten and first grade consisted of 114 and 255 students respectively, and the control groups consisted of 58 and 68 students respectively. Students in the kindergarten experimental groups used Waterford curriculum for more than 1,000 minutes, and students in the control groups used the curriculum for less than 400 minutes. Students in the first grade experimental group used Waterford curriculum for more than 1,000 minutes, and students in the control group did not use the curriculum.

Materials

The Waterford Early Learning Program (WEL). The Waterford Early Learning Program (WEL) includes the Waterford Early Reading Program (ERP) and the Waterford Early Math and Science Program (EMS). The program offers a comprehensive, computer-adaptive developmentally appropriate literacy and mathematics 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 individual rate of growth throughout the complete curriculum.

Developmental Reading Assessment (DRA). The DRA is a standardized reading test used to determine a student's instructional level in reading. The DRA is administered individually to students.

Mobile Classroom: The Dynamic Indicators of Basic Early Literacy Skills (mCLASS: DIBELS Next) and Math (mCLASS: Math). The assessments evaluate the early literacy and mathematics skills of students. The assessments were designed to determine which students need additional assistance in developing early literacy or math skills.

Procedure

Kindergarten students were expected to use ERP and EMS for fifteen minutes per day, five days per week, throughout the school year, and first grade students were expected to use ERP and EMS for thirty minutes per day, five days per week, throughout the school year.

In the first district, the DRA was administered at the beginning and end of the year. In the second district, the mCLASS: DIBELS Next assessment and the mCLASS: Math assessment were administered at the beginning, middle, and end of the year.

Findings

District 1

Kindergarten

Group Differences Using an Independent Samples t-test. An independent samples *t*-test examining group differences in DRA end of year scores between the experimental group and the control group was conducted (Tab. 1). Analysis of end of year scores revealed a significant difference between groups, $t(1, 1030) = -2.37$, $p < .05$, due to higher end of year scores made by experimental students ($M = 5.99$) than by control students ($M = 4.39$). Effect size ($d = 0.45$).

Group Differences by Low-SES Using a Two-Way ANOVA. A two-way ANOVA was conducted to examine the effects of Waterford curriculum and lunch program on end of year DRA scores (Tab. 1). There was no significant interaction between the effects of lunch program and Waterford curriculum on DRA end of year scores, $F(2, 1026) = 0.68$, $p = .505$. Simple effects analysis showed that for students with free lunch, students in the experimental group scored slightly higher than the control group, but the difference was not significant.

	Experimental			Control			
	M	*SD*	*N*	*M*	*SD*	*N*	*p*
Overall	5.99	3.52	1004	4.39	3.21	28	.02*
Low-SES	4.85	2.82	381	4.00	4.08	10	.44

*$p < .05$, **$p < .01$

Table 1: District 1 Kindergarten DRA End of Year Scores

First Grade

Group Differences Using an ANCOVA. An ANCOVA examining group differences in DRA end of year scores while covarying for DRA beginning of year scores was conducted (Tab. 2). Analysis of DRA end of year scores, while covarying for DRA beginning of year scores, revealed a significant difference between groups, $F(1, 1113) = 9.14$, $p < .01$, due to higher end of year scores made by experimental students ($M = 18.54$) than by control students ($M = 16.87$). Effect size ($d = 0.33$).

Group Differences by Low-SES Using a Two-Way ANCOVA. A two-way ANCOVA was conducted to examine the effects of Waterford curriculum and lunch program on DRA end of year scores, covarying for DRA beginning of year scores (Tab. 2). There was no significant interaction between the effects of lunch program and Waterford curriculum on DRA end of year scores, covarying for DRA beginning of year scores, $F(2, 1109) = 0.45$, $p = .639$. Simple effects analysis showed that for free lunch, students in the experimental group significantly outperformed students in the control group.

	Experimental			Control			
	M	*SD*	*N*	*M*	*SD*	*N*	*p*
Overall	18.54	5.05	1064	16.87	5.26	52	.00**
Low-SES	18.02	5.48	377	16.01	5.09	29	.01**

*$p < .05$, **$p < .01$

Table 2: District 1 First Grade DRA End of Year Scores

District 2

Early Reading Program - Kindergarten

Group Differences Using Analysis of Covariance (ANCOVA). ANCOVAs examining group differences in mCLASS: DIBELS Next end of year scores while covarying for middle of year scores were conducted (Tab. 3). Beginning of year scores were not used as a covariate because of students' low usage of ERP in the fall semester.

	Experimental			Control			Statistical	
	M	*SD*	*N*	*M*	*SD*	*N*	Measure	*p*
Letter Naming Fluency	58.36	12.14	108	53.26	21.33	27	5.77	.02*
NWF - Correct Letter Sounds	52.74	30.20	108	44.72	17.92	27	4.06	.05*
NWF - Whole Words Read	9.21	12.40	108	4.11	6.32	27	7.39	.01**

*$p < .05$, **$p < .01$

Table 3: District 2 Kindergarten End of Year Scores Covarying for Middle of Year Scores

Group Differences by Lunch Program Using ANCOVAs. Two-way ANCOVAs were conducted to examine the effects of Waterford curriculum and lunch program on end of year scores while covarying for middle of year scores for each substrand (Tab. 4).

Letter Naming Fluency. There was no significant interaction between the effects of lunch program and Waterford curriculum on Letter Naming Fluency end of year scores, covarying for middle of year scores, $F(2, 121) = 1.36$, $p = .247$. Simple effects analysis showed that for free lunch, students in the experimental group significantly outperformed students in the control group.

Nonsense Word Fluency - Correct Letter Sounds. There was a significant interaction between the effects of lunch program and Waterford curriculum on Nonsense Word Fluency - Correct Letter Sounds end of year scores, covarying for middle of year scores, $F(2, 121) = 6.30$, $p < .05$. Simple effects analysis showed free lunch students' scores in the experimental group were slightly higher than in the control group, but the difference was not significant.

Nonsense Word Fluency - Whole Words Read. There was no significant interaction between the effects of lunch program and Waterford curriculum on Nonsense Word Fluency - Whole Words Read end of year scores, covarying for middle of year scores, $F(2, 121) = 1.10$, $p = .297$. Simple effects analysis showed that free lunch students' scores in the experimental group were slightly higher than in the control group, but the difference was not significant.

	Experimental			Control			
	M	*SD*	*N*	*M*	*SD*	*N*	*p*
Letter Naming Fluency	58.33	12.64	48	51.81	16.17	14	.03*
NWF - Correct Letter Sounds	47.90	18.47	48	47.78	19.68	14	.98
NWF - Whole Words Read	6.95	6.21	48	3.68	6.92	14	.22

*$p < .05$, **$p < .01$

Table 4: District 2 Kindergarten End of Year Scores Covarying for Middle of Year Scores by Low-SES

Early Math and Science Program – Kindergarten

Group Differences Using ANCOVAs. ANCOVAs examining group differences in mCLASS: Math end of year scores while covarying for beginning of year scores were conducted (Tab. 5).

	Experimental			Control			Statistical	
	M	*SD*	*N*	*M*	*SD*	*N*	Measure	*p*
Number Identification	32.38	12.81	114	28.25	11.08	57	7.34	.01**
Quantity Discrimination	30.80	9.58	114	28.12	7.28	57	4.30	.04*

*$p < .05$, **$p < .01$

Table 5: District 2 Kindergarten End of Year Scores Covarying for Beginning of Year Scores

Group Differences by Lunch Program Using Two-Way ANCOVAs. Two-way ANCOVAs were conducted to examine the effects of Waterford curriculum and lunch program on end of year scores while covarying for beginning of year scores for each substrand (Tab. 6).

Number Identification. There was no significant interaction between the effects of lunch program and Waterford curriculum on Number Identification end of year scores, covarying for beginning of year scores, $F(2, 164) = 1.10$, $p = .334$. Simple effects analysis showed that for free lunch, students' scores in the experimental group were slightly higher than in the control group, but the difference was not significant.

Quantity Discrimination. There was no significant interaction between the effects of lunch program and Waterford curriculum on Quantity Discrimination end of year scores, covarying for beginning of year scores, $F(2,$

164) = 2.41, p = .093. Simple effects analysis showed that for free lunch, students' scores in the experimental group were slightly higher than in the control group, but the difference was not significant.

	Experimental			Control			
	M	*SD*	*N*	*M*	*SD*	*N*	*p*
Number Identification	29.89	11.63	59	27.40	10.95	35	.21
Quantity Discrimination	28.57	7.83	59	27.74	7.45	35	.60

*p < .05, **p < .01

Table 6: District 2 Kindergarten End of Year Scores Covarying for Beginning of Year Scores by Low-SES

Early Math and Science Program –First Grade

Group Differences Using ANCOVAs. ANCOVAs examining group differences in mCLASS: Math end of year scores while covarying for beginning of year scores were conducted (Tab. 7).

	Experimental			Control			Statistical	
	M	*SD*	*N*	*M*	*SD*	*N*	Measure	*p*
Number Facts	14.02	4.05	68	12.69	3.61	255	9.06	.00**
Quantity Discrimination	42.17	9.58	68	39.78	9.09	255	5.88	.02*
Missing Number	25.90	6.89	68	23.12	6.49	255	15.07	.00**
Next Number	23.77	5.99	68	22.09	6.04	255	6.18	.01*

*p < .05, **p < .01

Table 7: District 2 First Grade End of Year Scores Covarying for Beginning of Year Scores

Group Differences by Lunch Program Using Two-Way ANCOVAs. Two-way ANCOVAs were conducted to examine the effects of Waterford curriculum and lunch program on end of year scores while covarying for beginning of year scores for each substrand (Tab. 8).

Number Facts. There was no significant interaction between the effects of lunch program and Waterford curriculum on Number Facts end of year scores, covarying for beginning of year scores, $F(2, 310) = 2.86$, $p = .059$. Simple effects analysis showed that for free lunch, students in the experimental group significantly outperformed students in the control group.

Quantity Discrimination. There was no significant interaction between the effects of lunch program and Waterford curriculum on Quantity Discrimination end of year scores, covarying for beginning of year scores, $F(2, 310) = 0.37$, $p = .694$. Simple effects analysis showed that for free lunch, students in the experimental group significantly outperformed students in the control group.

Missing Number. There was no significant interaction between the effects of lunch program and Waterford curriculum on Missing Number end of year scores, covarying for beginning of year scores, $F(2, 310) = 0.32$, $p = .730$. Simple effects analysis showed that for free lunch, students in the experimental group significantly outperformed students in the control group.

Next Number. There was no significant interaction between the effects of lunch program and Waterford curriculum on Next Number end of year scores, covarying for beginning of year scores, $F(2, 310) = 0.26$, $p = .775$. Simple effects analysis showed that free lunch students' scores in the experimental group were slightly higher than in the control group, but the difference was not significant.

	Experimental			Control			
	M	*SD*	*N*	*M*	*SD*	*N*	*p*
Number Facts	14.12	4.06	32	12.24	3.55	123	.00**
Quantity Discrimination	42.54	8.12	32	39.33	9.56	123	.03*
Missing Number	25.07	5.37	32	22.80	6.58	123	.03*
Next Number	23.08	4.47	32	21.76	5.84	123	.19

*p < .05, **p < .01

Table 8: District 2 First Grade End of Year Scores Covarying for Beginning of Year Scores by Low-SES

Discussion

The findings of the current study support the hypothesis that implementing adaptive CAI software into curricula can help students improve early reading and math skills more effectively than traditional in-class instruction alone. Students who used CAI software throughout the school year in addition to traditional classroom learning scored significantly higher on reading and math assessments than their peers who did not use the software. These results can be generalized, as the positive effect of CAI was seen with multiple measures of assessment, and across a variety of populations. Students who qualified for free lunch also had consistently higher scores when given access to CAI, though their scores were not always significantly higher.

It is important to note that students who had a higher amount of usage throughout the school year had higher gains and end of year scores than students who had a low amount of usage, or who only had access to the software for part of the school year. This suggests that in order to gain the full benefits of CAI, students should have access to and use the software regularly. Overall, CAI, when implemented with fidelity, can be an effective supplement for teaching early reading and math skills to students in a classroom setting, and closing the socioeconomic achievement gap.

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