

Long-Term and Early Effects of Computer-Assisted Instruction in Early Childhood

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Abstract. Longitudinal studies are an infrequently used but essential means to identify effective literacy interventions for young readers. This study aimed to identify whether computer-adaptive technology, specifically Waterford Early Learning (WEL), in the early grades leads to lasting impacts on literacy skills. In this study, the literacy skills of second grade students in a public school district in Maryland were measured at the end of the 2017-2018 school year using a district administered literacy assessment. Scores were analyzed in three distinct comparisons: overall effects, comparing students who used computer-assisted instruction (CAI) to those who did not; long-term effects, comparing students who were assessed one year after using CAI to those with no CAI usage; and early effects, comparing students who used CAI for three years compared to two years. Students who used CAI in kindergarten, first grade, and second grade significantly outperformed students who did not use the program in any year on two measures of reading skills. Moreover, students who used the program in kindergarten and first grade but did not use in second grade significantly outperformed their control counterparts who did not use the program when assessed one year after, indicating the long-term effects of the program on students' literacy skills. Students who used the program for all three years outperformed students who did not start using the program until first grade, indicating that beginning educational technology programs as early as possible makes a lasting impact on students' literacy skills. Overall, technology may be a beneficial addition to the traditional classroom setting.

Keywords: Literacy, Technology, Long-term Effects, Early Childhood.

1 Introduction

In 2002, the National Early Reading Panel (NERP) convened to identify the prerequisites for students from birth to age five to acquire literacy skills [1]. This panel utilized rigorous research to argue that if students come to kindergarten unprepared as five-year-olds, they will not be able to catch up to their more practiced peers in literacy skills, documenting that early skills are a direct link to literacy later in life. The panel recommended utilizing strong interventions as early as possible and providing for students' early literacy development so that they can succeed academically when

learning to read in elementary school [1]. Although the NERP was a historic panel that paved the way for the importance of early childhood education, their recommendation for high-quality research to demonstrate the necessity of early interventions has not been met, and research has had some difficulty keeping pace with every emerging trend in early literacy instruction. Early childhood education is extremely important, but more rigorous longitudinal research is necessary to fully comprehend the impact of what aspects of high-quality education encompass.

Early education makes the greatest impact on students' skills academically. Students enrolled in a high-quality preschool program significantly outperformed their peers who had not enrolled in preschool on fourth grade reading and math measures, years after they were in preschool [2]. On the other hand, a separate study of reading fluency skills found that at the end of second grade, students were found to have lower scores if they began the school year with lower reading fluency skills [3]. The authors noted that students' reading self-concept impacted their reading fluency skills; at the beginning of the year students felt they were at a deficit, and this had a tangible impact on learning. A study of students' reading scores in second and third grade after a first grade implementation of response to intervention (RTI) lead to a conclusion that students who need interventions will likely need further interventions in the future; moreover, reading interventions need to be more effective specifically in areas of fluency and comprehension in order to provide for students who are falling behind in their grade level [4]. A recent study of the cumulative effects of literacy deficits found that half of students with below average literacy skills at the start of kindergarten did not reach an average level of reading achievement by the end of eighth grade; of the students who did improve, most came from privileged backgrounds [5]. RTI involves individualized interventions for students who need them the most, so perhaps reading interventions are necessary for early elementary school students. These results demonstrate the negative outcomes from the lack of early interventions on literacy skills; however, a longitudinal study investigating the impact of full day kindergarten compared to half day kindergarten found no long-lasting significant benefits of full day kindergarten through ninth grade [6]. This study implies that earlier and greater access to education did not have a lasting effect on students' skills. More rigorous research is necessary to explore and fully comprehend all avenues for high-quality education [7]; perhaps educational technology can assist early elementary school students in reaching their full potential.

Educational technology is one aspect of modern high-quality education that merits further study. The sheer amount of technologically enabled resources available to teachers and educators has expanded exponentially in recent decades [8]. Educational technology has changed the classroom, and this epoch shift does not look to be reversible [9]. Research has explored the implications of this new normal; one meta-analysis investigating test scores of elementary school students found that educational technology was one of the leading factors contributing to student success [10]. Individualized, differentiated, technology-based reading instruction has been found to be more impactful than large group reading instruction for first and second grade [11]. In one longitudinal study examining the impact of technology for learning outcomes and assessing students' third grade scores as pretest and fifth grade scores as posttest, students who used laptops significantly outperformed students who did not use laptops

in both literary response, analysis, and writing strategies, but not in reading comprehension [12]. In a separate longitudinal study that followed students from kindergarten through third grade, using iPads in classrooms improved academic achievement as measured by English language arts scores but not math achievement [13]. Educational technology can have structural advantages over traditional teacher focused approaches in terms of adaptivity, responsiveness and engagement. Computer-assisted instruction (CAI) refers to an approach that leverages the advantages of technology to improve learning outcomes. Unlike a lecture model, which by necessity has to be tailored to the mean competency of the class, CAI can adapt its content and difficulty to each individual students' skills and preparedness [14]. CAI can provide meaningful feedback in real time, reinforcing learning and addressing issues as both emerge [15]. CAI can also encourage engagement with the material itself through interactive media, songs, and games [16].

While research shows that early elementary school years are critical to achieve literacy [17], hardly any studies can demonstrate that technology specifically has a long-lasting impact on students' early literacy skills. A recent meta-analysis found that longitudinal research that can speak to the impact of some of the most commonly employed pieces of technology, such as laptops and personal computers on literacy skills, is rare [18]. There is also a limited body of longitudinal research which has focused on literacy outcomes for elementary school age students. According to one meta-analysis, reading interventions targeted at students in later elementary school grades may have longer lasting effects than interventions targeted at earlier grades [19]. When results for reading interventions were followed up one year after the intervention, effects for older elementary school students were found to be more than three and a half times those found for younger elementary school students. This contradicts the traditional perspective, which stresses the importance of addressing any reading weaknesses as early as possible. A randomized controlled trial investigating the impact of students using the Responsive Classroom (RC) approach for three years found that students in schools assigned to the intervention condition outperformed students in schools assigned to the control condition in neither reading nor math; however, greater fidelity of implementation of RC practices was related to greater math and reading achievement [20]. However, a different meta-analysis called this relationship between fidelity and learning outcomes into question when it found no significant relationship between reading outcomes and the fidelity with which a given intervention was implemented across 43 studies [21]. Although one study found that individual differences in spelling abilities in students are relatively stable across grades [22], none of these results are particularly long-lasting. Interventions that use technology may be able to provide stronger longitudinal effects in improving students' reading skills, but further research is needed to demonstrate the point.

In this study, students used a computer-adaptive reading program for up to three years, in kindergarten, first grade, and/or second grade, in a public school district. It was hypothesized that if students used the program for three years, they would outperform students who did not use the program, demonstrating an overall effect of computer-assisted instruction (CAI); if students were tested one year after using the program, they would outperform students who did not use the program, demonstrating a long-term

effect of CAI; and if students used the program for three years, they would outperform students who used the program for two years by starting one year later, demonstrating an early effect of CAI.

2 Methods

2.1 Participants

This longitudinal study consisted of second grade students ($N = 5,002$) enrolled in a large suburban public school district in Maryland during the 2017-2018 school year.

The three years of usage experimental group ($n = 2,108$) included students who used WEL for more than 100 minutes during kindergarten (2015-2016), first grade (2016-2017), and second grade (2017-2018). These students form the experimental groups when assessing overall and early effects.

The kindergarten and first grade usage experimental group ($n = 288$) included students who used WEL for more than 100 minutes during kindergarten (2015-2016) and first grade (2016-2017) but used the program for less than 100 minutes during second grade (2017-2018). These students form the experimental group when assessing long-term effects.

The no usage control group ($n = 593$) included students who used WEL for less than 100 minutes during all three school years. These students form the control group when assessing overall and long-term effects.

The first grade and second grade usage control group ($n = 729$) included students who used WEL for more than 100 minutes during first grade (2016-2017) and second grade (2017-2018) but used the program for less than 100 minutes during kindergarten (2015-2016). These students form the control group when assessing early effects.

2.2 Materials

Waterford Early Learning (WEL). WEL offers a comprehensive, computer-adaptive reading curriculum for 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.

District-Administered Literacy Assessment. The literacy assessment administered by the school district consisted of two strands for second grade students, Dictation Sounds and Dictation Words.

2.3 Procedure

In kindergarten, experimental students were expected to use WEL for fifteen minutes per day, five days per week, and in first grade and second grade, experimental students were expected to use WEL for thirty minutes per day, five days per week. Usage was tracked within the program and monitored weekly, and total minutes of the adaptive

curriculum usage for the school year per group was calculated. The district literacy assessment was administered to all students at the end of the 2017-2018 (second grade) school year, and all groups were assessed at the end of second grade.

3 Findings

3.1 Three Years of Usage vs. No Usage: Overall Effects

For three years of usage compared to no usage, the experimental group included students who used WEL for more than 100 minutes during kindergarten (2015-2016), first grade (2016-2017), and second grade (2017-2018). The control group included students who used WEL for less than 100 minutes during all three school years.

Group Differences Using Independent Samples *t*-tests. Independent samples *t*-tests were conducted to examine group differences in end of second grade scores between experimental and control groups (see Fig. 1).

Dictation Sounds. Analysis of Dictation Sounds end of second grade scores revealed a significant difference between groups, $t(1, 673) = -3.97, p < .01$, due to higher end of second grade scores made by experimental students ($M = 63.66$) than by control students ($M = 60.46$). Effect size ($d = 0.19$).

Dictation Words. Analysis of Dictation Words end of second grade scores revealed a significant difference between groups, $t(1, 729) = -3.10, p < .01$, due to higher end of second grade scores made by experimental students ($M = 17.46$) than by control students ($M = 16.48$). Effect size ($d = 0.15$).

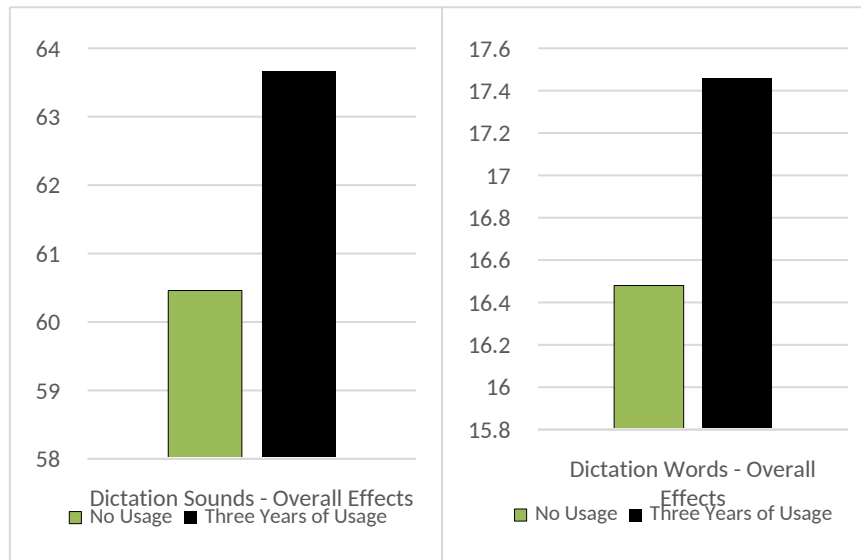


Fig. 1. Three years of usage vs. no usage end of second grade scores

3.2 Kindergarten and First Grade Usage vs. No Usage: Long-Term Effects

For kindergarten and first grade usage compared to no usage, the experimental group included students who used WEL for more than 100 minutes during kindergarten (2015-2016) and first grade (2016-2017) but used the program for less than 100 minutes during second grade (2017-2018). The control group included students who used WEL for less than 100 minutes during all three school years.

Group Differences Using Independent Samples *t*-tests. Independent samples *t*-tests were conducted to examine group differences in end of second grade scores between experimental and control groups (see Fig. 2).

Dictation Sounds. Analysis of Dictation Sounds end of second grade scores revealed a significant difference between groups, $t(1, 702) = -2.30, p < .05$, due to higher end of second grade scores made by experimental students ($M = 63.06$) than by control students ($M = 60.46$). Effect size ($d = 0.17$).

Dictation Words. Analysis of Dictation Words end of second grade scores did not reveal a significant difference between groups, $t(1, 821) = -1.18, p = .231$; however, end of second grade scores made by experimental students ($M = 17.06$) were higher than scores made than by control students ($M = 16.48$).

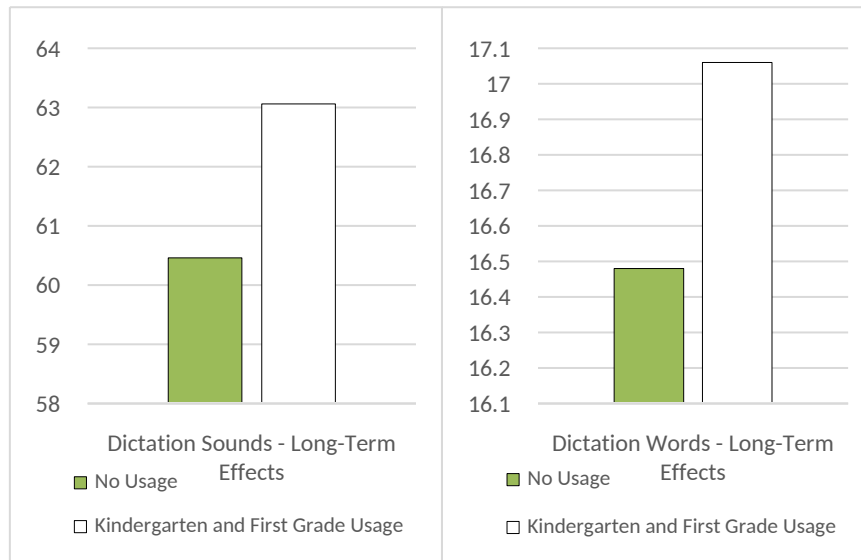


Fig. 2. Kindergarten and first grade usage vs. no usage end of second grade scores

3.3 Three Years of Usage vs. First Grade and Second Grade Usage: Early Effects

For three years of usage compared to first grade and second grade usage, the experimental group included students who used WEL for more than 100 minutes during kindergarten (2015-2016), first grade (2016-2017), and second grade (2017-2018). The control group included students who used WEL for more than 100 minutes during first grade (2016-2017) and second grade (2017-2018) but used the program for less than 100 minutes during kindergarten (2015-2016).

Group Differences Using Independent Samples *t*-tests. Independent samples *t*-tests were conducted to examine group differences in end of second grade scores between experimental and control groups (see Fig. 3).

Dictation Sounds. Analysis of Dictation Sounds end of second grade scores revealed a significant difference between groups, $t(1, 1029) = -3.44, p < .01$, due to higher end of second grade scores made by experimental students ($M = 63.66$) than by control students ($M = 61.50$). Effect size ($d = 0.15$).

Dictation Words. Analysis of Dictation Words end of second grade scores revealed a significant difference between groups, $t(1, 1126) = -2.10, p < .05$, due to higher end of second grade scores made by experimental students ($M = 17.46$) than by control students ($M = 16.92$). Effect size ($d = 0.09$).

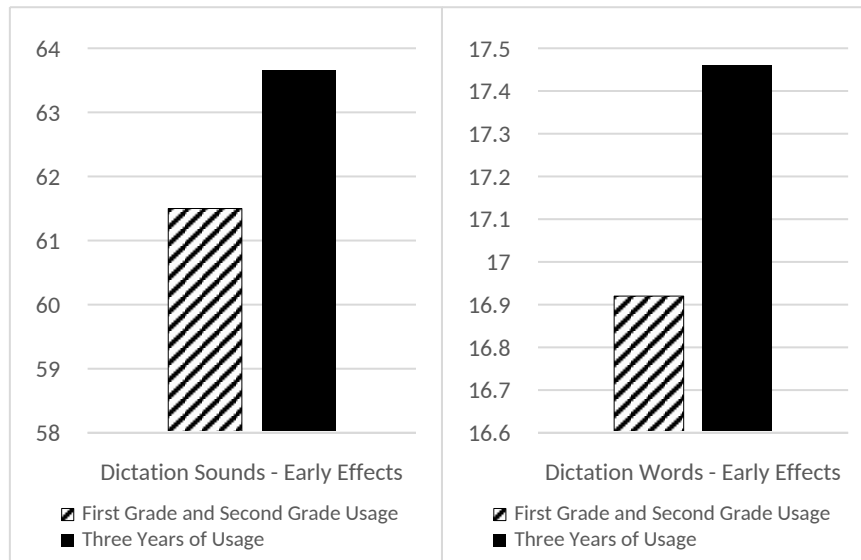


Fig. 3. Three years of usage vs. first grade and second grade usage end of second grade scores

4 Conclusions

Results from the current longitudinal study showed that students' test scores generally benefited from the use of CAI. Dictation Sounds and Dictation Words scores of students who used WEL for more than 100 minutes during each of the three school years in this study were significantly higher than scores of students who used WEL for less than 100 minutes during each of the three school years. The structural advantages of CAI, adaptivity, responsiveness, and engagement, enabled students who used WEL to outperform students who did not. This finding adds to the body of research exploring the efficacy of CAI.

Results also offered support for the long-term effects of CAI on students' test scores. When assessed one year after students used WEL, students who used the program for more than 100 minutes while in kindergarten and first grade had significantly higher Dictation Sounds scores than students who used WEL for less than 100 minutes during each of the three school years. Knowledge gained while using CAI was retained long after use of the program stopped. Use of WEL established a stable foundation on which future lessons were built. This finding adds to the limited body of research looking into the long-term implications of CAI usage.

Finally, results demonstrated an effect of the early use of CAI. When assessed at the end of second grade, students who started using WEL while in kindergarten, with more than 100 minutes of usage in each of the three school years, significantly outperformed students who started using a year later in first grade, with more than 100 minutes of usage only in first and second grade, on Dictation Sounds and Dictation Words. Students who started using WEL earlier benefited more than students who started using the program later. An implication of this finding is that in order to achieve the best

possible results for students, CAI interventions should be designed to be implemented as early as possible.

The current longitudinal study did not assess demographic factors which may have influenced learning outcomes. The sample was also drawn from a single school district, which reduces generalizability. Future research into the long-term effects of CAI could be improved with a large, diverse sample drawn from multiple locations and a thorough demographic analysis.

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