Chapter 14
Dosage Effects of CAI on Literacy Skills

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Abstract While support exists in the literature for the efficacy of computer-assisted instruction (CAI), possible dosage effects have rarely been investigated. Kindergarten students enrolled in a public school district in Idaho were randomly assigned on the class level to an experimental or control condition during the 2017–2018 school year. Students in the experimental condition used CAI, and students in the control condition received traditional literacy instruction for the same amount of instructional time. A standardized assessment was administered at the beginning and end of the school year. Students who used CAI demonstrated greater gains from beginning of year to end of year on all strands of the STAR Early Literacy assessment; however, gains were not statistically significant. Experimental students who used the program for at least 1,500 min throughout the school year significantly outperformed their control counterparts on all strands of STAR Early Literacy. These findings support the use of technology in teaching literacy skills to young learners and highlight the moderating effect that dosage has on learning outcomes.

Keywords Early childhood · Literacy · Technology

14.1 Introduction

Computer-assisted instruction (CAI) describes an approach to education that takes advantage of technology in the learning process. The structural advantages of technology allow CAI to employ novel media to hold a student's attention, respond in real time, and individualize lessons [1]. CAI can engage students by presenting different forms of interactive and instructional media to foster engagement with a lesson. CAI can be responsive and provide information in real time about which answers are correct or incorrect, giving students a sense of progress and teachers the necessary data to assist their students. CAI can individualize a lesson to each student's specific

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V. L. Uskov et al. (eds.), *Smart Education and e-Learning 2019*,
Smart Innovation, Systems and Technologies 144,
https://doi.org/10.1007/978-981-13-8260-4_14

needs, providing appropriate and challenging content for each student. When well designed and well implemented, research has shown CAI to improve reading [2, 3] and arithmetic [4] skills in young learners.

Overall, research exploring the efficacy of CAI has identified modest but positive effects on learning outcomes [5–7]. A recent synthesis of meta-analyses from 1982 to 2015 found that technology in the classroom was beneficial to students across all grade levels, $g = 0.29$ [6]. This represents a slight but noticeable decrease in effect size from the findings of a prior landmark second-order meta-analysis, $g = 0.35$ [7]. This synthesis also noted an inverse relationship between the quality of a study and the magnitude of effect reported, with relatively poorer quality studies reporting larger effects. Additionally, publication date scaled with study quality, with more recent studies assessed at relatively higher quality. A separate recent second-order meta-analysis examining CAI found a strong, positive relationship between the fidelity of CAI implementation, the amount of available training and support, level of teacher and student enthusiasm and use, and learning outcomes [5]. Rigorous evidence-based research is more necessary than ever as old assumptions are reassessed, and the relationship between the level of usage and student-level outcomes should be examined.

The randomized controlled trial (RCT) is one approach to carrying out high-quality, methodologically sound research. The RCT has long been considered the last word in evidence-based hypothesis testing [8, 9]. This model creates equal groups by randomly assigning all participants into separate conditions on the basis of chance prior to the administration of an intervention. As groups should be rendered statistical twins by the randomization process, any statistically significant changes after the intervention can be causally attributed to the intervention. RCTs with low attrition are the only experimental approach that can meet What Works Clearinghouse's standards without reservations [10]. RCTs provide, and are possibly the only design that can provide, educators, parents, and policy-makers with the rigorously derived, statistically supported facts they need to make decisions that affect students' lives.

RCTs in early education have been scarce in general [11], and research, RCT or otherwise, directly addressing the level of CAI usage as a moderating effect of students' academic performance has been rare [5]. When the dosage of CAI was examined, some support was found for learning outcomes scaling with higher levels of usage. A recent study examining technology use patterns in students found that frequent use of technology was associated with a broadly defined set of media savvy skills, referred to as the "digital native" skill set, which facilitated navigation in a technological world [12]. One notable finding of a meta-analysis looking into learning outcomes for K-12 students was that young learners using supplemental CAI for more than thirty minutes per week tended to outperform students using the same program for less than thirty minutes per week [13]. Involved parents, motivated administrators, and enthusiastic teachers have historically been meaningful predictors of both CAI usage and academic success of kindergarten students, and this has been demonstrated in a recent large-scale study of kindergarten students [14]. Students' extracurricular use of personal devices and educational software significantly predicted academic success in a study of sixth- and eighth-grade students [15]. In a separate study of fourth-grade students, even when various demographic factors including gender and socioeconomic status were controlled for, individual usage was a meaningful predictor of academic success in reading, math, and science [16]. CAI, when used to fidelity with sufficient dosage, has been an effective tool to help students meet their full potential.

However, despite modest overall positive effects, some CAI studies have found no benefits to students' learning outcomes: In a recent meta-analysis, more than one-third of the sampled studies showed students' performances decreased with the use of CAI [5]. Recent case studies found that students scored worse following a CAI intervention than they did before receiving the intervention [17]. The literature has provided evidence to suggest that the dosage of CAI either is irrelevant or could even be counterproductive at higher levels of usage [12, 15]. Frequent use of technology has been found to negatively correlate with the skillset traditionally considered productive learning behaviors [12]. Students with a higher dose of technology use were rated lower on measures of controlling multitasking-skills and reflection while reading. Additionally, in a study involving middle school students, classroom-level indicators for a successful implementation, i.e., teacher buy-in, classroom immersion, and support, were not meaningful predictors of students' academic success [15]. Because of these conflicting findings, more educational research is needed to explore the relationship between the dosage and efficacy of CAI.

The current study was conducted to explore the impact of CAI on the learning outcomes of young students. It was hypothesized that students who used a CAI literacy program would outperform students who did not use CAI on a standardized measure of literacy skills. An examination of students who used the program to fidelity also provided insight into a potential dosage effect.

14.2 Methods

14.2.1 Participants

This study consisted of kindergarten students ($N = 730$) enrolled in a public school district in Idaho during the 2017–2018 school year. The experimental group consisted of kindergarten students who were randomly assigned on the class level to use Waterford Early Learning (WEL). The control group consisted of kindergarten students who were randomly assigned at the class level to receive traditional literacy instruction.

14.2.2 Materials

Waterford Early Learning. The program offers a comprehensive, computer-adaptive pre-reading and reading curriculum for pre-kindergarten through secondgrade 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.

Standardized Test for the Assessment of Reading (STAR) Early Literacy. The Standardized Test for the Assessment of Reading (STAR) Early Literacy includes subtests assessing Alphabetic Principle, Concept of Word, Visual Discrimination, Phonemic Awareness, Phonics, Structural Analysis, Vocabulary, Sentence-Level Comprehension, Paragraph-Level Comprehension, and Early Numeracy.

14.2.3 Procedure

Experimental and control groups were determined by random assignment at the class level. Twenty-four kindergarten classes across 12 schools participated in the study. Twelve kindergarten classes were randomly assigned to the experimental condition: Students ($n = 382$) in these classes were expected to use Waterford Early Learning (WEL) during the 2017–2018 school year for 15 min per day, 5 days per week. Twelve kindergarten classes were assigned to the control condition: Students ($n = 348$) in these classes received traditional literacy instruction for the same amount of time that the experimental group received CAI instruction. Thus, overall exposure to literacy instruction was the same for both groups.

The STAR Early Literacy assessment was administered to students at the beginning and end of the school year. Analysis was conducted for all students who were assessed, as well as for a recommended usage subsample of experimental students with over 1,500 min of usage.

14.3 Findings

14.3.1 All Students

Experimental group students ($n = 336$) and control group students ($n = 289$) completed the STAR Early Literacy assessment.

Group Differences in Gains Using Independent Samples *t*-tests. Independent samples *t*-tests examining gains made from beginning of year to end of year were conducted (see Figs. 14.1 and 14.2).

Scaled Score. Analysis of Scaled Score gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = 0.86$, $p = 0.390$; however, gains made by experimental students ($M = 111.27$) were slightly higher than those made by control students ($M = 104.30$).

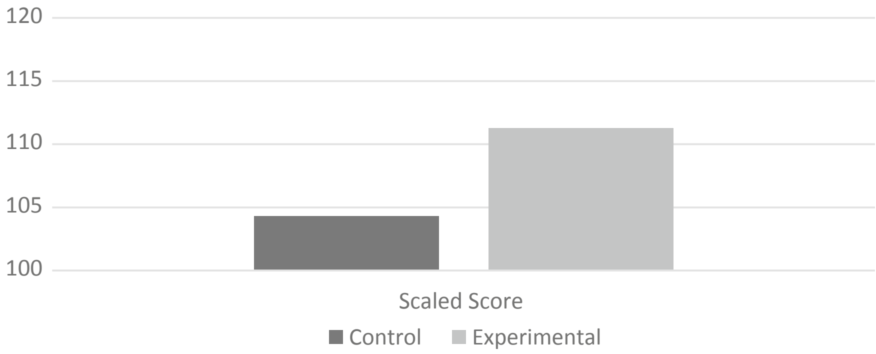

Fig. 14.1 STAR early literacy scaled score gains from beginning of year to end of year

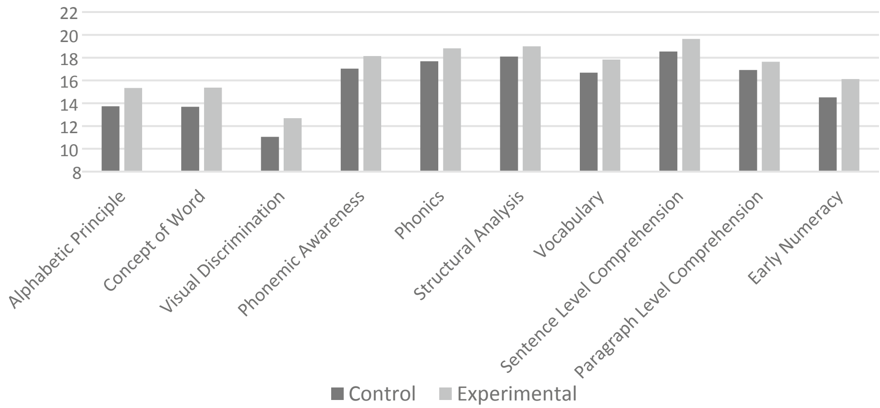

Fig. 14.2 STAR early literacy gains from beginning of year to end of year by strand

Alphabetic Principle. Analysis of Alphabetic Principle gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -1.37$, $p = 0.172$; however, gains made by experimental students ($M = 15.34$) were slightly higher than those made by control students ($M = 13.73$).

Concept of Word. Analysis of Concept of Word gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -1.41$, $p = 0.160$; however, gains made by experimental students ($M = 15.37$) were slightly higher than those made by control students ($M = 13.69$).

Visual Discrimination. Analysis of Visual Discrimination gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -1.56$, $p = 0.118$; however, gains made by experimental students ($M = 12.69$) were slightly higher than those made by control students ($M = 11.05$).

Phonemic Awareness. Analysis of Phonemic Awareness gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623)$

$= -0.84$, $p = 0.403$; however, gains made by experimental students ($M = 18.14$) were slightly higher than those made by control students ($M = 17.03$).

Phonics. Analysis of Phonics gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -0.82$, $p = 0.410$; however, gains made by experimental students ($M = 18.81$) were slightly higher than those made by control students ($M = 17.68$).

Structural Analysis. Analysis of Structural Analysis gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -0.64$, $p = 0.525$; however, gains made by experimental students ($M = 19.00$) were slightly higher than those made by control students ($M = 18.10$).

Vocabulary. Analysis of Vocabulary gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -0.88$, $p = 0.378$; however, gains made by experimental students ($M = 17.83$) were slightly higher than those made by control students ($M = 16.69$).

Sentence-Level Comprehension. Analysis of Sentence-Level Comprehension gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -0.76$, $p = 0.447$; however, gains made by experimental students ($M = 19.64$) were slightly higher than those made by control students ($M = 18.54$).

Paragraph-Level Comprehension. Analysis of Paragraph-Level Comprehension gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -0.54$, $p = 0.586$; however, gains made by experimental students ($M = 17.64$) were slightly higher than those made by control students ($M = 16.92$).

Early Numeracy. Analysis of Early Numeracy gains made from beginning of year to end of year did not reveal a significant difference between groups, $t(1, 623) = -1.37$, $p = 0.187$; however, gains made by experimental students ($M = 16.12$) were slightly higher than those made by control students ($M = 14.51$).

14.3.2 Recommended Usage

Experimental group students ($n = 142$) in the recommended usage subsample and control group students ($n = 289$) completed the STAR Early Literacy assessment.

Group Differences in Gains Using Independent Samples *t*-tests. Independent samples *t*-tests examining gains made from beginning of year to end of year were conducted (see Figs. 14.3 and 14.4).

Scaled Score. Analysis of Scaled Score gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.58$, $p < 0.05$,

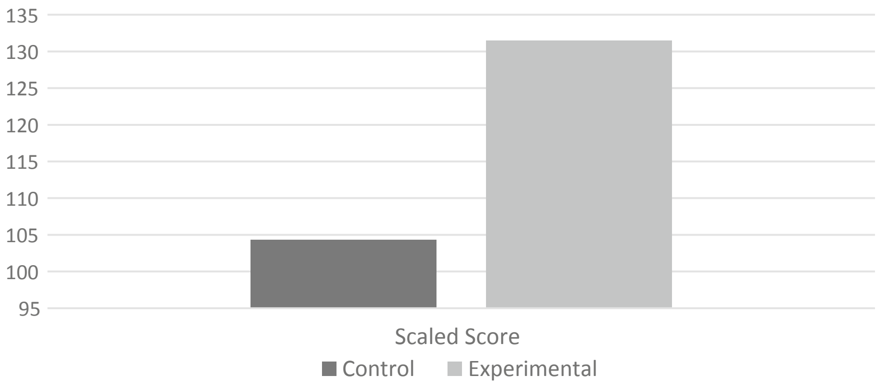

Fig. 14.3 Recommended usage STAR early literacy scaled score gains from beginning of year to end of year

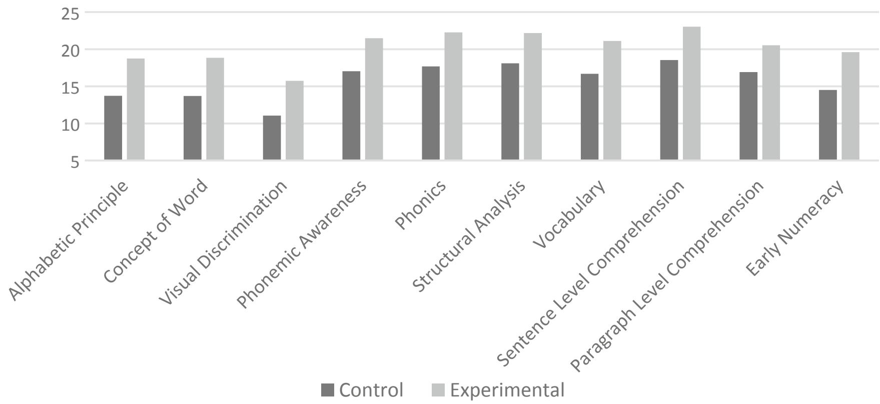

Fig. 14.4 Recommended usage STAR early literacy gains from beginning of year to end of year by strand

due to the higher gains made by experimental students ($M = 131.51$) than by control students ($M = 104.30$). Effect size ($d = 0.26$).

Alphabetic Principle. Analysis of Alphabetic Principle gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 225) = -2.99$, $p < 0.01$, due to the higher gains made by experimental students ($M = 18.75$) than by control students ($M = 13.73$). Effect size ($d = 0.31$).

Concept of Word. Analysis of Concept of Word gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 226) = -3.04$, $p = < 0.01$, due to the higher gains made by experimental students ($M = 18.84$) than by control students ($M = 13.69$). Effect size ($d = 0.31$).

Visual Discrimination. Analysis of Visual Discrimination gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 221) = -3.09, p < 0.01$, due to the higher gains made by experimental students ($M = 15.75$) than by control students ($M = 11.05$). Effect size ($d = 0.32$).

Phonemic Awareness. Analysis of Phonemic Awareness gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.58, p < 0.05$, due to the higher gains made by experimental students ($M = 21.49$) than by control students ($M = 17.03$). Effect size ($d = 0.26$).

Phonics. Analysis of Phonics gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.56, p < 0.05$, due to the higher gains made by experimental students ($M = 22.26$) than by control students ($M = 17.68$). Effect size ($d = 0.26$).

Structural Analysis. Analysis of Structural Analysis gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.22, p < 0.05$, due to the higher gains made by experimental students ($M = 22.18$) than by control students ($M = 18.10$). Effect size ($d = 0.23$).

Vocabulary. Analysis of Vocabulary gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.61, p < 0.01$, due to the higher gains made by experimental students ($M = 21.11$) than by control students ($M = 16.69$). Effect size ($d = 0.27$).

Sentence-Level Comprehension. Analysis of Sentence-Level Comprehension gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.39, p < 0.05$, due to the higher gains made by experimental students ($M = 23.04$) than by control students ($M = 18.54$). Effect size ($d = 0.25$).

Paragraph-Level Comprehension. Analysis of Paragraph-Level Comprehension gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 429) = -2.09, p < 0.05$, due to the higher gains made by experimental students ($M = 20.54$) than by control students ($M = 16.92$). Effect size ($d = 0.21$).

Early Numeracy. Analysis of Early Numeracy gains made from beginning of year to end of year revealed a significant difference between groups, $t(1, 228) = -2.96, p < 0.01$, due to the higher gains made by experimental students ($M = 19.61$) than by control students ($M = 13.73$). Effect size ($d = 0.30$).

14.4 Conclusions

In this study, students who were randomly assigned to use CAI performed similarly to their control counterparts on gains made from the beginning to the end of the year on a kindergarten early literacy assessment; on the other hand, students who used the program for at least 1,500 min over the course of their kindergarten school year had significantly higher gains from beginning of year to end of year across literacy strands on the assessment than their control counterparts. These results indicate that while CAI can be an effective tool for improving student-level learning outcomes, dosage should not be overlooked. Using CAI to fidelity is important to reap the benefits of technology. This study demonstrates very clearly that students' grades do not necessarily improve through mere proximity to a computer monitor. Students who did not use the product as intended, for 15 min per day, 5 days per week on average, did not demonstrate higher literacy gains than students who did not use the product. A successful implementation requires both time and the commitment to maintain usage. Overall, CAI can potentially positively impact students' early literacy skills, but it must be used properly to reach that potential.

This study involved students from only one grade within one school district. As a result, generalizability could have been impacted by local geographic or cultural confounds. More school districts need to be included in future studies to maximize generalizability of findings.

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