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The influence of a computer-adaptive reading program on fourth-grade students' reading achievement scores

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Abstract

Students' time spent learning is a predictive factor of academic achievement, but instructional time is often compressed due to internal and external interruptions. Incorporating technology into reading instruction may be a way to support teachers as they navigate competing demands on instructional time. To investigate the association between reading achievement and time spent on a technology-based reading program, this study examined how time spent utilizing a computer-adaptive, curriculum-based reading program influenced reading achievement for students at all reading ability levels. Fourth-grade students' (N=16,717) overall reading and reading comprehension achievement growth were examined accounting for (a) students' usage of a computer-adaptive reading program, and (b) students' initial reading achievement level. Findings indicated that fourth-grade students' overall and reading comprehension scores improved for students at all reading levels. Further, students that used the supplemental curriculum for the recommended weekly minutes demonstrated greater gains. Students in the lowest quartile made the greatest gains.

***Keywords*:** computer-adaptive learning, reading achievement, time-on-task, school and home usage

Instructional time in school is limited and can be compressed as a result of non-instructional activities (Smith, 2000). External, and internal interruptions such as announcements, behavioral interruptions, class visitors, and students coming in and leaving the classroom all create disruptions that may lead to reduced focus on curriculum which could hamper achievement further, as new modes of classroom instruction and attendance requirements are shifting because of the COVID-19 pandemic face to face instructional time has further been narrowed. With limited instructional time in the school day, teachers and administrators are tasked with finding solutions to provide equitable instruction for all students. Since students' time on task--or time spent engaged in an educational activity--is a predictor of academic achievement (Fisher et al., 2015; McLean et al., 2016; Vincent, 1999), it is important to investigate solutions that provide students more instructional opportunities.

Strategies for optimizing instructional time include incorporating computer assisted technologies such as instructional programs, games, and mobile applications (apps). As students' ability to read is central in their long-term academic achievement, schools and teachers have incorporated computer-adaptive programs to bolster students' reading skills and to provide supplemental practice. Content-specific computer programs (e.g. reading and mathematics) have been employed in classrooms in an effort to engage students and extend learning in content specific areas to improve achievement (Cheung & Slavin, 2012). Efforts to determine the influence of computer-adaptive programs on students' reading have been limited (Putman, 2017). In general, Taylor, Frye, and Maruyama (1990;) called for additional research examining students' investment of time in reading activities on their reading achievement scores. Similarly, Rosenshine (2015), indicated the need to investigate the influence of time as it relates to students' academic levels in relation to making reading progress. While these calls for further

research were not specifically related to computer adaptive reading, they were inclusive of investigating time related to reading and reading progress. CARPs are tools to supplement and enhance reading instruction.

Teachers are significant contributors to reading achievement and how computer-adaptive reading programs (CARPs) are utilized in schools by students). CARPs like other supplemental reading programs do not supplant the teacher or core instruction. Rather, these types of programs aim to enhance instruction. Supplemental reading programs that extend and support core reading programs have been instrumental in strengthening reading achievement scores (Englert et al., 2005). Knowing the importance and potential of a CARP and the significance of time allotted to reading, the purpose of our study was to investigate the influence of fourth-grade students' time spent using a CARP on their reading achievement scores. First, we examined how students' overall reading scores varied over time using four assessment points. Then we further investigated if/how reading achievement scores varied by time spent using a CARP and academic reading level (quartiles).

Students' Time on Task and Their Learning

Students' time on task in an educational activity may be quantified by the actual minutes spent engaged in the learning task. Students' time spent learning is a predictive factor in their academic achievement. Specifically, the more time students invest in their learning, the greater their academic achievement scores (You, 2016). One factor that contributes to students' learning of a skill or acquiring expertise can include the time they spent honing their skills through performing the desired competency. In the instance of reading, students are taught phonics, phonemes, reading comprehension, vocabulary, and spelling. To practice these components of reading

separately or collectively and build reading fluency, learner confidence, and self-efficacy requires a time investment (Locher & Pfost, 2020).

Students' engagement and motivation are important considerations when evaluating time on task in relation to academic achievement (Bryant et al., 2015; Fredricks et al., 2004; Okolo et al.,1993). Students who are intrinsically motivated to read are more engaged in reading activities, leading to higher achievement (Schiefele et al., 2012; Stutz et al., 2017). When students are not motivated or engaged, they tend to be less focused. In a classroom environment utilizing CARPs as an addition to core instruction, teachers serve an essential role in supporting students' time on task by monitoring students and redirecting the students' efforts towards the supplemental reading activities.

Computer-Assisted Instruction (CAI), CARPs, and Time on Task

Computer-Assisted Instruction (CAI) can be a part of reading instruction and has been a curricular option since before the birth of the personal computer (Atkinson & Hansen, 1966). CAI harnesses the power of technology to deliver interactive multimedia instruction to student. In some cases, CAI may not be adaptive or personalized, whereas CARPs are adaptive and adopt to students' knowledge level. Theoretical foundations of CAI and CARPs relate to Vygotsky's (1978) zone of proximal development (ZPD). According to Vygotsky (1978) students learn most effectively when they are gently challenged with more difficult or intricate tasks in accordance with their developmental level by more expert members of the learning community. In CARPs, computer algorithms serve to monitor and gentle prompt students' progress. Students' learning is continually assessed and lessons are adjusted to provide this scaffolding process with additional oversight from the students' teachers to ensure learning remains challenging but supportive."

When determining the effectiveness of CAIs to improve students' reading achievement, results vary. CAI was found to improve first-grade students' reading achievement through independent reading practice for 160 minutes over a four-week period (Englert et al., 2005). However, Ness et al. (2013) found that early elementary school students ($N = 37$) engaging in 100 minutes a week for an entire school year of a different reading program yielded no statistical difference between the control and experimental group. Cheung and Slavin (2013) described time intensity in their reading meta-analysis of CAI. The effect size for low intensity programs with struggling readers, ≤ 75 minutes a week (.08) and high-intensity program, > 75 minutes a week (.19) were low and not statistically significant. However, the greater the amount of time students spent reinforcing reading skills, the greater the effect size. Supplemental CAIs and CARPs can offer students practice, improving their pivotal reading skills

CARPs are digital tools that can provide students additional self-paced time to develop their reading skills in an environment that minimizes performance anxiety and peer competition. CARPs foster literacy skills in early elementary (Crossley & McNamara, 2016; Giamcomo Dina et al., 2016; Schneider et al., 2015). In a randomized controlled trial (RCT) conducted with 22 Kindergarten classes ($N = 430$), students in the CARP treatment group, on average, outperformed students in the control group after using a CARP 15 minutes a day for a total of 75 minutes per week (Shamiret al., 2019). Likewise, second-grade students ($N = 1562$) who had high CARP usage, 250 minutes per week, demonstrated greater achievement growth than those ($n = 784$) who minimally (under 300 minutes for the year) and those ($n = 778$) who moderately (over 2000 minutes) used the program (Shamiret al., 2019). In both cases, students' amount of time using the CARP contributed to their academic achievement.

Other time related affordances of CARPs include increased: (a) instructional time, (b) silent reading, and (c) real-time analytics. Instructional time enhancements can be realized by both students and teachers. Students can receive individualized instructional reinforcement as needed and at their own pace through the use of a CARP. Further, when students use a CARP, they are engaged in silent reading when prompted with passages, a known contributor to reading achievement (Taylor et al., 1990). As a result, teachers may be able to leverage students' time using a CARP for small group instruction and planning (Baker et al., 2017). Additionally, reports generated from a CARP (e.g., activity, progress, and formative assessment) save teachers' time by providing analytics about students' reading abilities to aid in planning individual, small group, and whole class instruction. CARPs digital assessments that guide instruction have been determined to improve achievement among young readers in cases when the teacher uses and has been adequately trained to harness assessment analytics to differentiate instruction (Connor et al., 2007).

Responding to the call for research on reading achievement and time-related effects by academic levels (Rosenshine, 2015; Yeşil, 2019), the purpose of our study was to examine fourth grade students' reading achievement growth as measured by *Istation's Indicators of Progress Advanced Reading* (ISIP-AR), in terms of students' (a) minutes of CARP usage and(b) academic achievement level As a result, the following research questions guided the investigation:

RQ1: How do all students' overall reading achievement scores change over the course of an academic school year, by achievement level, as determined by initial quartile?

RQ2: What, if any, are the overall reading achievement differences between those who use the computer-adaptive supplemental reading curriculum with fidelity (30 minutes per week) and those who do not, after controlling for the effects of their initial achievement quartile?

RQ3: What, if any, are the reading comprehension achievement differences between those who use the computer-adaptive supplemental reading curriculum with fidelity (30 minutes per week) and those who do not after controlling for the effects of their initial achievement quartile?

Method

Participants

The sample of our study included fourth-grade students (N = 16,717, 49% female and 51% male of those reported; see Table 1) from a large Southeastern state in which the CARP had been funded through a state appropriation and adopted to varying degrees in districts and schools. The participants were included in the sample if they completed at least four benchmark assessments during the school year: (a) assessment at the beginning of the year (BOY) - either August, September, or October; (b) assessment at mid-year (MOY_1) - either November or December; (c) assessment at mid-year (MOY_2) - either January or February; and (d) assessment at the end of the year (EOY) - either March, April or May. These students' achievement level was measured by their reported quartile in the sample. Quartile one indicates those in the lowest achievement level in the most need of intensive reading intervention. Conversely, quartile four captures the achievement of those in the upper 25% of the sample, the most advanced students.

Table 1

Demographics of the Overall Sample (N=16,717)

Characteristic	*n*	*%*
Academic Level		
Quartile 1	4179	25
Quartile 2	4179	25
Quartile 3	4180	25

Quartile 4	4179	25
Gender[a]		
Male	4909	52
Female	4519	48
Title I Status		
Title I	12,861	77
Not Title I	3856	23
Locale[b]		
City	5078	31
Rural	621	4
Suburban	10,366	62
Town	561	3
Curriculum Use		
<900 minutes	9835	59
>900 Minutes	6882	41

[a] 56.4% Reported
[b] 99.5% Reported

Procedure

In our study, de-identified assessment and computer-adaptive, supplementary reading curriculum usage data were collected during the 2016-2017 school year from participants across the state. Students began using the CARP at the beginning of the school year in either August or September and continued using the CARP throughout the school year until the end of the year in May. The computer-adaptive, supplemental curriculum used in our study was the Istation reading program (IRP) The K-8 supplemental reading program addresses the five components for developing reading including: (a) phonics, (b) phonemic awareness, (c) vocabulary, (d) reading

comprehension, and (e) fluency (National Reading Panel [NRP], 2000). The Istation reading program progresses through lessons as students' reach mastery. The reading selections include both fiction and non-fiction texts. In situations where student data indicates a need for more instruction, lessons are adapted until mastery is met.

Some schools employed the program for formative and benchmarking assessments alone, while others utilized the computer-adaptive and/or small group or individual lesson plans suggested based on the formative assessments. These variations were employed at the school-level or, in other cases, based on the needs and motivations of teachers or reading coordinators.

Measures

Istation Indicators of Progress – Advanced Reading (ISIP-AR) Assessment. Students' reading achievement was measured using the Istation Indicators of Progress Advanced Reading (ISIP-AR) Assessment. ISIP-AR is a curriculum-based, computer-adaptive testing system for students in grades four through eight for continuous progress monitoring of students' reading abilities. The ISIP-AR test questions were built on two-parameter Item Response Theory (IRT). The assessment takes approximately 20 minutes to complete and is automatically scheduled to be taken monthly upon initial log-in for the month (Istation, 2019; Mathes, 2016). Fourth-grade students expected annual reading achievement growth on the curriculum-based assessment ranges from 71 points for those in the lowest academic level (up to the 20th percentile) to 101 points for students in the highest academic level (upwards of the 40th percentile) (Patarapichayatham, 2014).

Time on Task and Usage of the CARP. Time on task (minutes of usage), a known indicator of reading achievement growth (Englert et al., 2005), was measured in this study by the number of minutes students spent reading using the CARP at school. The reading time (time on task) did

not include time spent on benchmark or monthly formative assessments (approximately 20-30 minutes a month), nor did it account for other types of reading outside of the program (e.g. class reading). Likewise, the quality of time spent while using the program at school was not the focus of this study. However, it is assumed that the teachers were in the room with the students and monitored their use of the program, ensuring that students were not sitting idly staring at the computer screen, but appeared to be engaged with the program.

The CARP utilized in our study recommended 40 plus minutes of CARP usage per week for students at and below the 40th percentile; and 30 plus minutes for students above the 40th percentile (Istation, 2019). When considering a full school year as 30 weeks (to account for assessment periods, holidays, special programs, and days off school due to inclement weather), students in the lowest two quartiles should evidence about 1200 minutes of digital curriculum use during the school year, and those in the upper two quartiles should complete about 900 minutes during the school year. Those students that followed these timing guidelines were using the program with fidelity. For all students in this study, we considered curriculum use at plus or minus 900 minutes.

The CARP has a home component that can be used at any time for supplemental instruction and practice. The benefit of home usage is the 24-hour, seven day a week access to practice. Students can practice reading not constrained by the school calendar, inclement weather, weekends or holidays. As remote learning took place during the COVID-19 pandemic, students were able to practice reading as an adjunct to teacher instruction. However, in areas where Internet access is limited, students' use of the program at home may be impacted leading to inequitable access. The IRP publisher does not indicate a number of recommended minutes for home usage. However, since fidelity of use at school was the purpose of the study and fidelity of

use at home could not be unobtrusively measured by researchers, home usage was not examined in this study.

Data Analysis

Initial data were screened for outliers, missing values, and inconsistent patterns. For instance, students who had a score or a partial score but did not complete the assessment were not included in the dataset. Descriptive analysis of achievement growth was determined by examining the point differential from the beginning assessment to the concluding assessment. A repeated-measures analysis of covariance (ANCOVA) was conducted to determine the effects of using a CARP curriculum on reading achievement over the course of a school year considering the covariate of students' reading achievement quartile. Participants with four assessments were included in the analysis.

Results

The descriptive statistics for achievement are presented first followed by the inferential statistics by research question.

Descriptives Related to Overall Achievement by Quartile

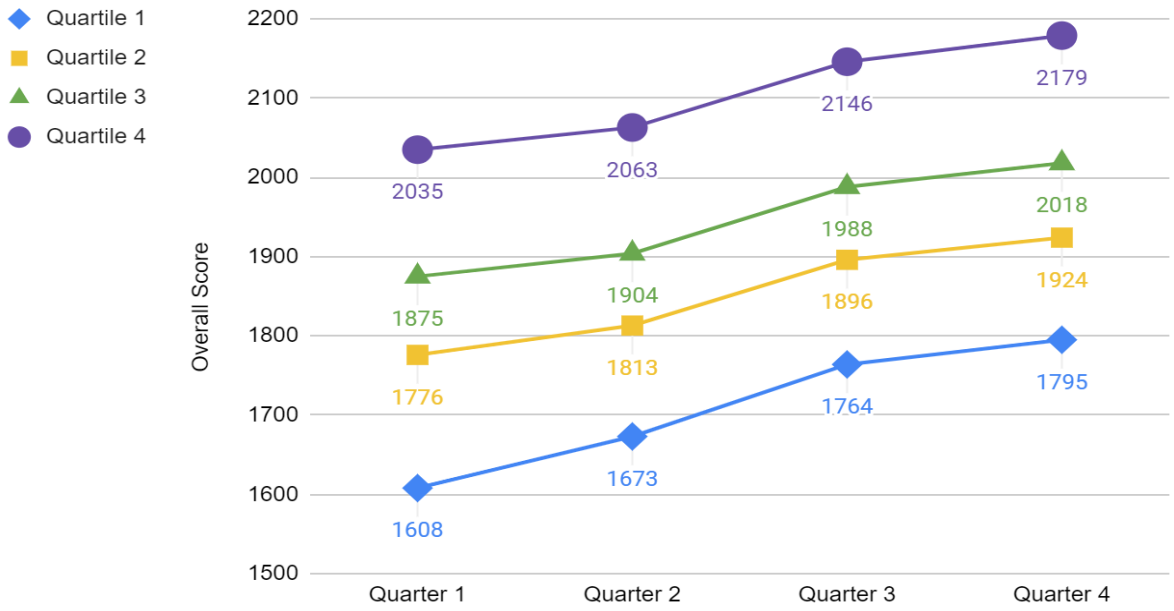
RQ1: How do all students' overall reading achievement scores change over the course of an academic school year, by achievement level, as determined by initial quartile? Figure 1 presents the assessment change and by initial quartile interaction, indicating that the scores significantly improved for students at all academic levels, with students in Quartile 1 (those at or below the 25th percentile) making the greatest gains in terms of increases in reading achievement scores. The differences in mean reading achievement scores between students at different academic levels (quartiles) remained throughout fourth grade. The distance between growth lines were

similar between the groups, meaning, on average, students in all academic levels made upward progress from the different assessment points.

Students evidenced statistically significant score improvement throughout the assessment periods from the beginning to the end of the year. Over the course of the school year in fourth grade, students' achievement scores in Quartile 1 increased on average by approximately 187 points, students' reading achievement scores in Quartile 2 increased on average by 148 points, students' reading achievement scores in Quartile 3 increased on average by 142 points and students' reading achievement scores in Quartile 4 increased on average by 144 points (see Figure 1). Mean gains for all students (despite academic level) for the year was 155 points. Mean scores by quarter for all students were (a) BOY: 1823.5, (b) MOY1: 1863.25, (c) MOY2: 1948.50, and (d) EOY: 1979. A paired sample t-test was conducted of Quarters 1-4 assessment to determine the correlation of the reading achievement mean scores between the first and fourth quarter. The correlation was .428, $p<.0001$.

Figure 1

Mean Reading Achievement Growth by Grade over the course of one School Year



Achievement Growth by Initial Quartile

A repeated measures analysis variance (ANOVA) was conducted to explore four points of reading achievement (a) BOY, (b) MOY_1, (c) MOY_2, and (d) EOY as measured by the ISIP-AR. There was a statistically significant difference between the four time points $F(3, 16713)= 21,798.78$, $p<.001$, $\eta 2$ .56 (large effect). Next, a repeated measure ANOVA by achievement and quartile indicated: achievement $F(3, 16713)= 22,211.42$, $p<.001$, $\eta 2$ .5, and achievement by quartile $F(9, 16,707)= 106.42$, $p<.001$, $\eta 2$ .019. Post hoc analysis of the estimated marginal means indicated a statistically significant difference by all quartiles at $p<.001$ with those in the lowest quartile making the greatest achievement in comparison to all of the other quartiles. Likewise, the difference between quarters was greatest between quarters one and four and the smallest growth took place between quarters three and four.

Achievement Growth with Fidelity for Overall Reading Achievement

Next, a repeated measure analysis of covariance (ANCOVA) between and within groups was conducted to answer RQ 2: What, if any, are the overall reading achievement differences between those who use the computer-adaptive supplemental reading curriculum with fidelity (30 minutes per week) and those who do not, after controlling for the effects of their initial achievement quartile? Groups included curriculum users (two levels), and overall reading achievement. Quartile (4 levels) was the covariate. An examination of the mean gains by curriculum use indicated that those students who met or exceeded the recommended average of 30 minutes of CARP usage gained 22 points more (168.86) than those that did not meet the IRPs guidelines (146.64). Findings from the ANCOVA indicated statistical significance of overall reading achievement, overall reading achievement and quartile, and overall reading achievement and curriculum use with small to large effect sizes (see Table 2).

Table 2

Interaction and Main between Subject Effects of Overall Reading Achievement, Curriculum Minutes, and Quartile

Effect	*F*	*p*	*ŋ2*
Overall Reading Achievement	*F*=(1, 16,716) = 11, 901.36	<.001	.41
Curriculum Use	*F*=(1, 16,714) = 38,261.91	<.001	.001
Quartile	*F*=(1, 16,714) = 15.01	<.001	.696
Overall Reading Achievement * Quartile	*F*=(1, 16,716) = 259.81	<.001	.015
Overall Reading Achievement * Curriculum Use	*F*=(1, 16,716) = 173.33	<.001	.010

Achievement Growth with Fidelity for Reading Comprehension

Next, we examined the reading comprehension scores in terms of fidelity of use (*n*=15,259). The reading comprehension test is a subtest of the overall ISIP-AR reading test that may be a particularly important determinant of fourth-grade reading success, given the increased importance of reading comprehension for upper-elementary grades (Chall & Jacobs, 1983), Analysis of reading comprehension over the four time points showed that scores improved 182.56 points from the grand mean average of 1888.40 to 2070.97. A repeated measure analysis of covariance (ANCOVA) between and within groups was conducted to answer RQ 3: What if any are the reading comprehension achievement differences between those who use the computer-adaptive supplemental reading curriculum with fidelity (30 minutes per week) and those who do not after controlling for the effects of their initial achievement quartile? Two points of reading achievement (a) BOY, and (b) EOY as measured by the ISIP-AR comprehension subtest were examined. Groups included curriculum users (2 levels), and overall reading achievement (4 timepoints). Quartile (4 levels) was the covariate. The results revealed a statistically significant effect for reading comprehension interaction, quartile, and curriculum use (see Table 3). Post hoc analysis indicated that reading comprehension scores improved the most for students between the first and the third quarter.

Table 3

Interaction and Main between Subject Effects of Reading Comprehension Achievement, Curriculum Minutes, and Initial Quartile

Effect	*F*	*p*	*ŋ2*
Reading Comprehension Achievement	*F*=(3, 15,256) = 1621.30	<.001	.536
Curriculum Use	*F*=(1, 15,256) = 28.12	<.001	.008
Quartile	*F*=(1, 15,256) = 21,566.59	<.001	.001

Overall Reading Achievement * Quartile	F=(3, 15,256) = 17.21	<.001	.006
Overall Reading Achievement * Curriculum Use	F=(3, 15,256) = 49.52	<.001	.007

Note. (n=15,259) included only those with a stand-alone comprehension subtest score

Discussion

Our study contributes to the limited evidence base regarding supplemental CARP for students in fourth grade and the influence of fidelity of use according to the recommended supplemental curriculum guidelines. The influence of time (supplemental curriculum usage minutes) spent using a CARP on fourth-grade students' overall reading achievement and reading comprehension were examined in terms of students' academic level (quartile). The findings are discussed in relation to the following topics: (a) overall reading achievement by academic level (quartile); and (b) the role of usage in terms of time on overall reading achievement and reading comprehension achievement.

Yearly Overall Reading Achievement by Quartile

When examining reading achievement over the course of the year by quartile, students' mean scores in the lowest quartile increased more than students in other quartiles. In other words, on average, students in the lowest quartile had greater achievement than those in the higher quartiles. However, the difference between the mid-range (143-148 points) and highest (144 points) quartiles was only one to five points. What this may mean is that even though the students in the lowest quartiles made great changes, it was not enough to overcome achievement gaps (Murphy, 2009). Like other reading related studies, achievement gains may be greater for students in the lowest quartile due to instructional policies that require students to spend more time on reading tasks and teachers' remedial focus (Christle & Yell, 2008; McGee, 2004). In some cases, assessment score gains tapered off during the last month of the school year, meaning the rate of increase that was

realized in other months was less than in May. Additionally, some May scores were lower than the prior months (e.g. March and April). Reasons for these phenomena may relate to a decreased emphasis during and after the standardized achievement assessment period (Herman & Golan, 1990). Curriculum developers, teachers, school and district instructional coaches, and curriculum providers may want to consider ways to engage students and instructors to maintain prior levels of use in order to maximize learning.

When examining both the overall and reading comprehension scores of students who utilized the supplemental CARP for the minimum recommended time guidelines, there were practical and statistically significant gains at all quartiles. Students who used the curriculum for the recommended time demonstrated greater gains than those who used less or no curriculum. While the IRP recommends 40 minutes of use for those in the 20th percentile (Istation, n.d.), our study found that 30 minutes of consistent weekly use of the supplemental program was sufficient for all quartiles.

Implications for Practice, Limitations, and Future Research

The most direct implication for practice concerns the role that fidelity of implementation may play in influencing reading achievement when using a supplementary, computer-adaptive reading program. Like Cheung and Slavin's (2012), meta-analysis of educational technology to improve reading, this study provides evidence that the CARP may be an effective way to increase reading achievement with teacher cooperation. In this study, the CARP is most effective when used for the recommended weekly time. Scheduling adequate weekly instructional time for CARP usage would be a first step for students to practice their reading. Teachers can be aided in their use of CARPs data analysis for instructional planning by school and district administrators via scheduling and access to other resources such as training. Students can be supported in practicing

the recommended time by having: (a) consistently functional technology, (b) the availability of spaces conducive to computer-assisted learning and (c) in the case of remote learning access to the Internet and devices. Clear communication from administrators that takes into consideration teachers' feedback about how and when to use the CARP with fidelity and how to incorporate CARP usage into instructional routines can encourage shared understandings of the role and importance of the program (Anthony, 2011).

A limitation of this study, like many other studies investigating students' use of self-directed programs, is the level of focus and persistence the students demonstrated when using the program (Bryant et al., 2015; Fredricks et al., 2004; Okolo et al., 1993). Even though in our study, time spent using the CARP was positively related to reading achievement scores (when accounting for different achievement levels), it is possible for students to be distracted. Another potential limitation is the length of the study, as the investigation was conducted over the course of one academic school year. A longitudinal study may provide additional information related to the effects of time over the course of several years, inclusive of the impact of the summer effect on reading (Campbell et al., 2019). Future research could include a longitudinal study considering time and other variables (e.g., online instruction during the COVID-19 pandemic, or increase access through the use of mobile devices).

Teachers could encourage students to use the CARPs both in and out of school to increase practice time in developing their reading skills. Circumstances like inclement weather (e.g. snow, hurricanes, and flooding) that prevent students from attending school can be alternative times for accessing a CARP out of school as utilities are renewed and students are still out of school (Campbell et al., 2019). While this study examined the aspect of time as it relates to students' reading achievement scores, other aspects of using a CARP were not investigated and warrant

further qualitative and quantitative examination, into students' motivation, engagement, the use of data analytics, and professional development. Further, investigations of CARP usage with other grade levels could inform all educational stakeholders who plan instructional time.

In summary, our study was a response to the call for more research related to reading achievement, and the effects of time, and students' academic level. Our findings provide support for the use of a supplemental CARP to compliment teachers' reading instruction. Moreover, students who read and practiced reading skills using a CARP with fidelity evidenced greater overall reading and reading comprehension achievement scores. Teachers' can leverage CARPs to support their face to face instruction thereby increasing their students opportunity to practice reading.

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