# USING TECHNOLOGY TO TEACH YOUNG LEARNERS MATH SKILLS

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## Abstract

Failing to master foundational math skills in early childhood puts students in jeopardy of later academic, personal, and professional deficits. Addressing these potential issues requires math interventions that can be employed early in the education process and are effective for all students. Computer-assisted instruction (CAI) can help students from all backgrounds improve their math skills and succeed academically. The current study evaluates a computer adaptive program's efficacy in teaching young learners key early math skills. Kindergarten students in a public school district in a midwestern state were given access to an adaptive math curriculum. The school district comprised predominantly African American/Black students (62%) and included a meaningful percentage of students enrolled in special education services (17%). Usage was monitored weekly for each student. The MAP Growth assessment was administered to all students at the beginning and end of the school year to assess statistical equivalence between students prior to the use of the computer-adaptive program and to assess differences in mathematical skill at the end of the school year between students who used the program to fidelity and those with less usage. It was hypothesized that students who used the program for a meaningful amount of time, to fidelity, during the school year would score higher on a math assessment at the end of the year compared to students who did not use the computer-adaptive program as much. Kindergarten students who used the computer-adaptive program for more than 1,500 minutes were considered to have used the program to fidelity, while low-use kindergarten students used the computer-adaptive program for less than 800 minutes. Independent samples *t*-tests examining group differences in end-of-year scores between high-use and low-use groups revealed that the high-use group using the computer-adaptive program performed significantly better than the low-use group across all subskills, including operations and algebraic thinking, numbers and operations, measurement and data, and geometry. Meaningful effect sizes were found across all subskills ranging from 0.25-0.38. The largest effects found were for the overall RIT math scores and the measurement and data subskill. Results were further parsed for students participating in and not participating in special education services. Students with special education services benefited immensely from high-use of the computer-adaptive program and achieved significantly higher scores than low-use students. This effect held for all mathematical subskills assessed. Additionally, students with special education services with high-use of the computer-adaptive program achieved scores comparable to low-use students without special education services, showing that both students with and without special education services benefited from using the math program in relative terms. The results of this study demonstrate the benefits that an early math-focused CAI intervention can bring to all students at a critical period in their education. In particular, this study indicates that CAI can be well suited to provide this essential early instruction to those students that may need it most.

Keywords: CAI, Math, Special Education Services

## 1 INTRODUCTION

Failure to master foundational math and numeracy skills in early childhood education can have a detrimental effect on later academic development. When not addressed promptly, these deficits grow, with increased missing ground to make up for year after year. A review of data from two benchmark longitudinal studies indicated that by the age of thirty, low numeracy specifically was associated with higher rates of unemployment and underemployment, higher risks for depression and low self-esteem, and a greater likelihood of facing arrest or criminal charges [1]. Notably, the effects of low numeracy in isolation were comparable to the impact of low numeracy and low literacy in combination. The retention of early mathematics is a predictor for later mathematical achievement and success in other subjects [2]. Early math intervention is essential for addressing deficits in a timely fashion.

Research has demonstrated the efficacy of early mathematics interventions. Meta-analyses reviewing studies on math interventions targeted at early grades found these approaches were consistently associated with medium effects when examining both pre-kindergarten and kindergarten ($d$ = 0.62) [3] as well as when including first grade ($g$ = 0.63) [4]. Programs that were deliberately targeted toward specific skills and interventions with consistent weekly usage (at least 120 minutes per week) tended to have stronger effects [3]. Though, concerningly, students who were assessed to be at high risk of mathematics difficulty benefited the least from math interventions [4]. Despite a broad base of support, some recent research has questioned the efficacy of early math interventions. Longitudinal research following up on students in elementary school who received an intervention in pre-kindergarten found that the program's impact fell well below the optimistic standards established in previous research [5]. It is important for educators to utilize early interventions that can provide students with an equal chance of success.

Literature has rightly emphasized the importance of achieving equity in math performance. Students from families experiencing poverty are especially vulnerable, as they are less likely to have access to academic resources when entering kindergarten [6]. Mathematics is particularly a concern of academic achievement for students in special education programs [7]. It is necessary to ensure that all students have equal access to tools that aid in acquiring foundational math skills.

Computer-assisted instruction (CAI) is a valuable tool in ensuring equitable academic outcomes. With CAIs, teachers can clearly view their students' knowledge by tracking meaningful data to manage classes with a wide range of skill levels [8]. CAI can also introduce students to different environments and contexts where they see various math problems. Providing students with more stimuli and responses repeatedly improves their mathematical fluency [9]. Giving students easy access to a diverse and stimulating learning environment will help them to retain the information better and learn more. CAI is cost-efficient, ensuring that it is easily accessible [10].

CAI can be particularly effective for improving math performance for at-risk and struggling students. CAI interventions have been shown to have a positive effect, in general, on mathematical achievement [11]. A synthesis of 45 studies of CAI math interventions specifically for struggling students indicated an overall medium effect ($d$ = 0.56), with a wide range of effect sizes noted when broken down by the type of CAI, employed [12]. CAI has been shown to be indispensable in helping students with disabilities succeed in mathematics. CAI provides students with disabilities with more access to mathematical facts by providing more engaging practice, which can help them bridge the skills gap between students with and without disabilities [13]. In addition, a study found that computer technologies had significantly increased mathematical achievement, especially for students in special education programs [14]. Due to technology's benefits for students with special education services, the Individuals with Disabilities in Education Act requires that assistive technology be considered for students in special education programs to promote their progress and participation in class [7]. Digital learning can give students with disabilities the boost they need to succeed academically. Students with a specific learning disability (SLD) could face unfair disadvantages without such early mathematical aid [15].

The current study evaluates CAI efficacy in teaching kindergarten students early math skills. It was hypothesized that students who used the program to fidelity during the school year would score higher on a math assessment at the end of the year compared to students who did not use the CAI program to fidelity.

# 2 METHODOLOGY

## 2.1 Participants

The sample for this study ($N$ = 559) consisted of kindergarten students enrolled in a public school district in Illinois during the 2021-2022 school year. The sample was 49% female, 62% African American/Black, and 22% Caucasian/White. 17% of the sample received special education services.

The experimental group ($n$ = 459) consisted of students who used the computer-assisted instruction program for more than 1,500 minutes. The control group ($n$ = 100) consisted of students who used the computer-assisted instruction program for less than 800 minutes.

## 2.2 Materials

### *2.2.1 Waterford Reading Academy (WRA)*

The Waterford Reading Academy (WRA) includes the Waterford Early Reading Program (ERP) and the Waterford Early Math and Science Program (EMS). 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 *Northwest Evaluation Association (NWEA) Measures of Academic Progress (MAP) Growth*

The MAP Growth is a valid assessment intended to measure individual achievement and growth for -kindergarten through twelfth-grade students on a range of skills. The skills considered relevant to kindergarten students for this study are Overall RIT Math, Operations and Algebraic Thinking, Number and Operations, Measurement and Data, and Geometry. Results are scored on a standardized Rasch Unit (RIT) scale.

## 2.3 Procedure

Students were expected to use WRA for fifteen minutes per day, five days per week. Usage was tracked within the program and monitored weekly, and the total minutes of usage were calculated. The MAP Growth Math assessment was administered to all students at the beginning and end of the school year to assess mathematical skills.

# 3 RESULTS

## 3.1 Baseline equivalence using independent samples *t*-tests

Independent samples *t*-tests were conducted to determine the baseline equivalence of pretest scores between experimental and control groups at the beginning of the school year. Across all subskills, baseline scores were not significantly different between the students in the experimental and control groups (see Table 1).

*Table 1. MAP Growth Math beginning of year scores by subskill.*

| | ***Experimental*** | | ***Control*** | | | |
|---|---|---|---|---|---|---|
| | ***N*** | ***M*** | ***N*** | ***M*** | ***t*** | ***p*** |
| Overall RIT Math | 439 | 137.60 | 65 | 136.77 | -0.60 | .546 |
| Operations and Algebraic Thinking | 432 | 136.39 | 65 | 135.22 | -0.67 | .505 |
| Numbers and Operations | 438 | 136.48 | 65 | 137.37 | 0.57 | .567 |
| Measurement and Data | 439 | 139.06 | 65 | 137.66 | -0.89 | .374 |
| Geometry | 438 | 139.08 | 65 | 136.74 | -1.35 | .177 |

## 3.2 Posttest group differences using independent samples *t*-tests

Independent samples *t*-tests were conducted to examine group differences in end-of-year scores between experimental and control groups (see Fig. 1).

*Overall RIT Math*.

Analysis of Overall RIT Math end-of-year scores revealed a significant difference between groups, $t(1, 557) = -3.44$, $p < .01$, due to higher end-of-year scores made by experimental students ($M = 156.08$) than by control students ($M = 151.16$). Effect size ($d = 0.38$).

*Operations and Algebraic Thinking*.

Analysis of Operations and Algebraic Thinking end-of-year scores revealed a significant difference between groups, $t(1, 556) = -2.24$, $p < .05$, due to higher end-of-year scores made by experimental students ($M = 155.75$) than by control students ($M = 152.06$). Effect size ($d = 0.25$)

*Number and Operations.*

Analysis of Number and Operations end-of-year scores revealed a significant difference between groups, $t(1, 557) = -2.70$, $p < .01$, due to higher end-of-year scores made by experimental students ($M = 156.20$) than by control students ($M = 152.10$). Effect size ($d = 0.30$).

*Measurement and Data*.

Analysis of Measurement and Data end-of-year scores revealed a significant difference between groups, $t(1, 135) = -3.32$, $p < .01$, due to higher end-of-year scores made by experimental students ($M = 154.50$) than by control students ($M = 148.79$). Effect size ($d = 0.37$).

*Geometry*.

Analysis of Geometry end-of-year scores revealed a significant difference between groups, $t(1, 557) = -3.19$, $p < .01$, due to higher end-of-year scores made by experimental students ($M = 157.70$) than by control students ($M = 152.10$). Effect size ($d = 0.35$).

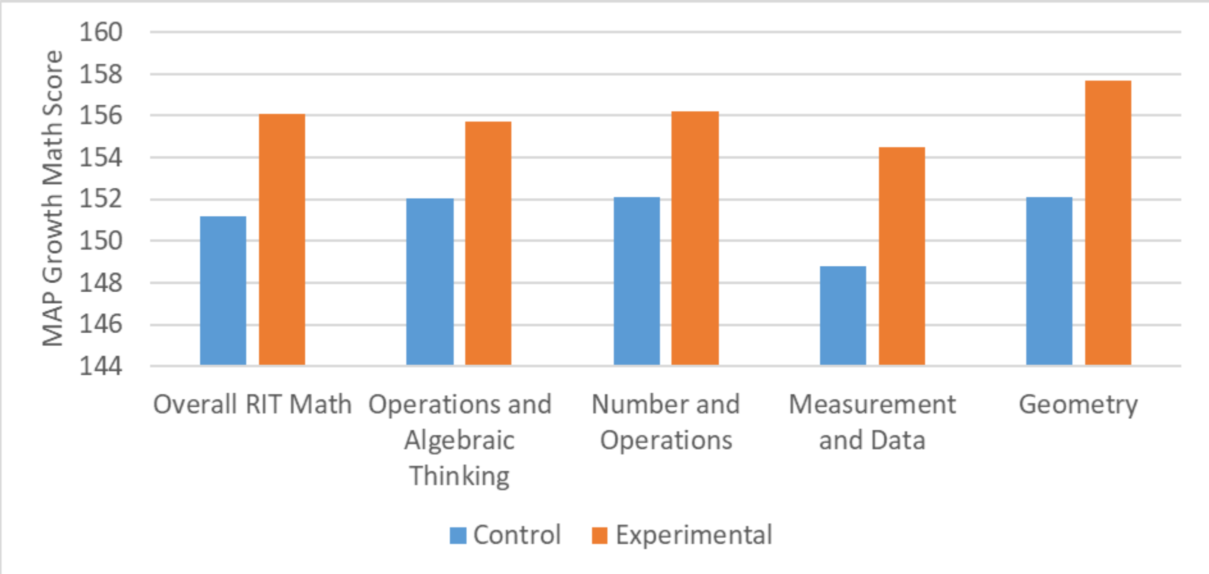


*Figure 1. Map Growth Math end-of-year scores by subskill.*

## 3.3 Posttest group differences using ANOVA – Overall RIT Math

A two-way ANOVA was conducted to examine the effects of WRA and special education services on Overall RIT Math end-of-year scores (see Fig. 2).

There was a significant interaction between the effects of special education services and WRA on Overall RIT Math end-of-year scores, $F(1, 555) = 5.31$, $p < .05$. Simple effects analysis showed that students with special education services in the experimental group significantly outperformed students in the control group. Students without special education services in the experimental group scored slightly higher than the control group, but the difference was not significant.

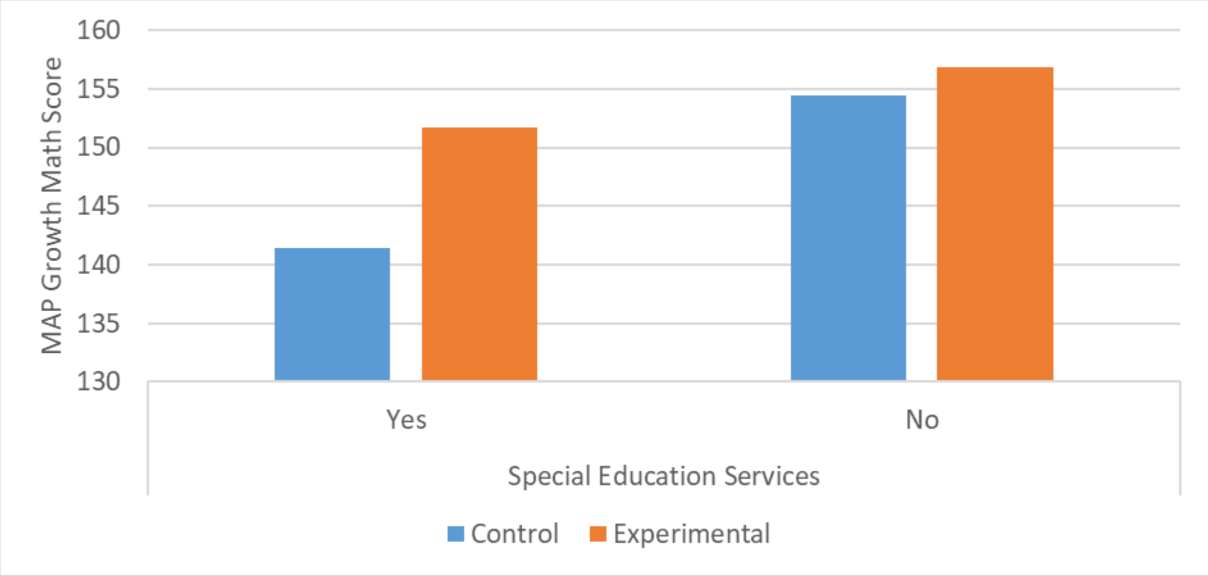


*Figure 2. Overall RIT Math end-of-year scores by special education services.*

## 3.4 Posttest group differences using ANOVA – Operations and Algebraic Thinking

A two-way ANOVA was conducted to examine the effects of WRA and special education services on Operations and Algebraic Thinking end-of-year scores (see Fig. 3).

There was no significant interaction between the effects of special education services and WRA on Operations and Algebraic Thinking end-of-year scores, $F(1, 554) = 1.48$, $p = .225$. Simple effects analysis showed that students with special education services in the experimental group significantly outperformed students in the control group. Students without special education services in the experimental group scored slightly higher than the control group, but the difference was not significant.

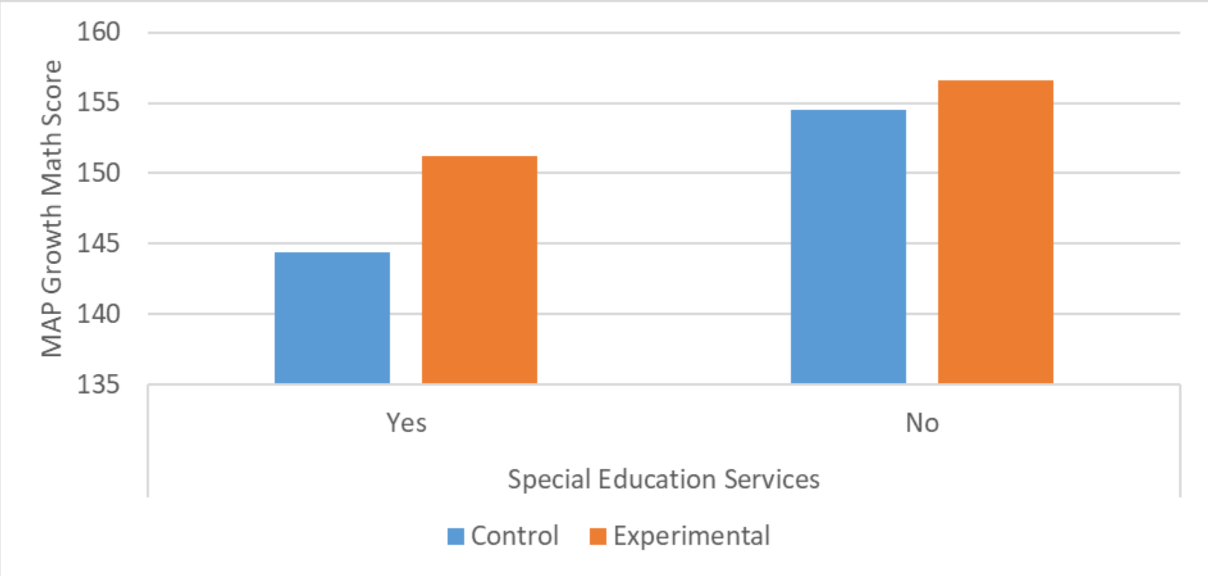


*Figure 3. Operations and Algebraic Thinking end-of-year scores by special education services.*

## 3.5 Posttest group differences using ANOVA – Number and Operations

A two-way ANOVA was conducted to examine the effects of WRA and special education services on Number and Operations end-of-year scores (see Fig. 4).

There was a significant interaction between the effects of special education services and WRA on Number and Operations end-of-year scores, $F(1, 555) = 7.66$, $p < .01$. Simple effects analysis showed that students with special education services in the experimental group significantly outperformed students in the control group. Students without special education services in the experimental group scored slightly higher than the control group, but the difference was not significant.

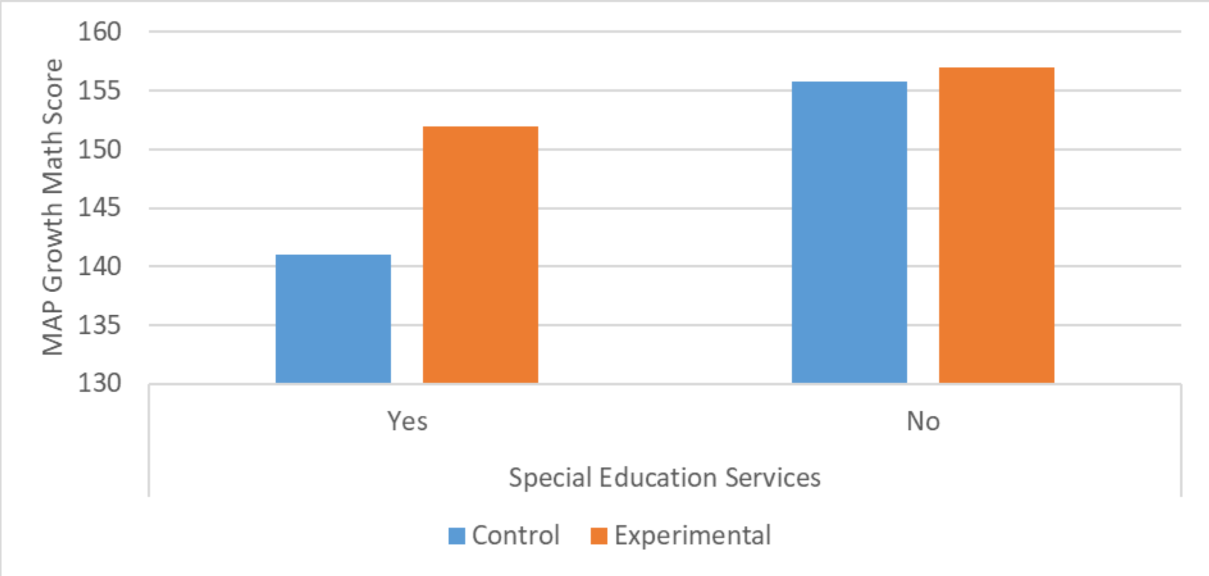


*Figure 4. Number and Operations end-of-year scores by special education services.*

## 3.6 Posttest group differences using ANOVA – Measurement and Data

A two-way ANOVA was conducted to examine the effects of WRA and special education services on Measurement and Data end-of-year scores (see Fig. 5).

There was no significant interaction between the effects of special education services and WRA on Measurement and Data end-of-year scores, $F(1, 555) = 2.79$, $p = .095$. Simple effects analysis showed that for students with special education services and students without special education services, students in the experimental group significantly outperformed students in the control group.

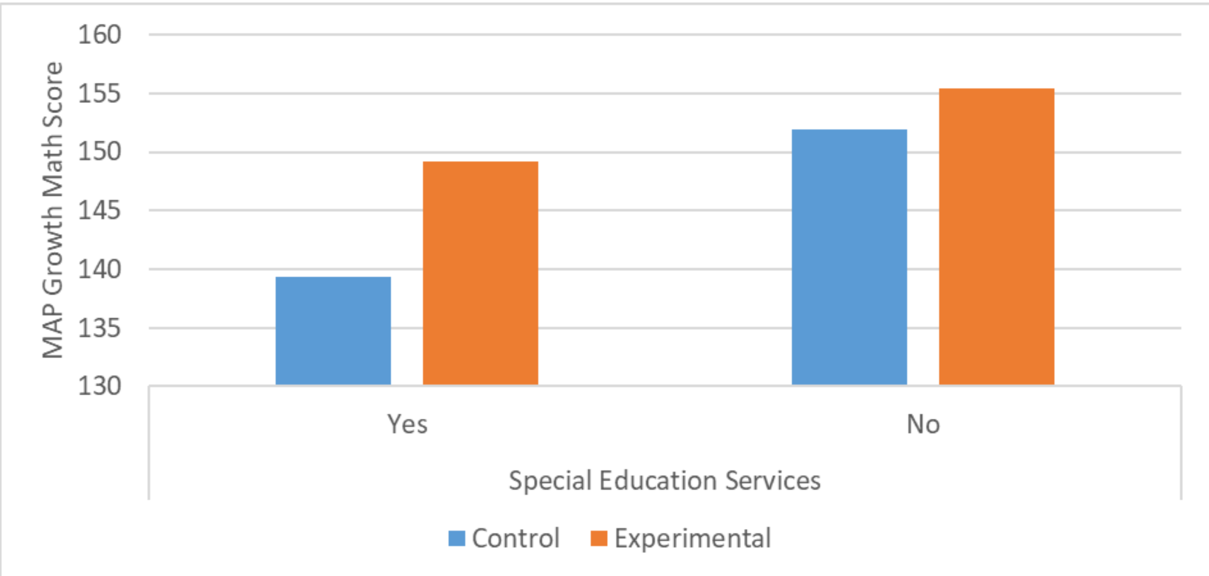


*Figure 5. Measurement and Data end-of-year scores by special education services.*

## 3.7 Posttest group differences using ANOVA – Geometry

A two-way ANOVA was conducted to examine the effects of WRA and special education services on Geometry end-of-year scores (see Fig. 6).

There was no significant interaction between the effects of special education services and WRA on Geometry end-of-year scores, $F(1, 555) = 3.66$, $p = .056$. Simple effects analysis showed that students with special education services in the experimental group significantly outperformed students in the control group. Students without special education services in the experimental group scored slightly higher than the control group, but the difference was not significant.

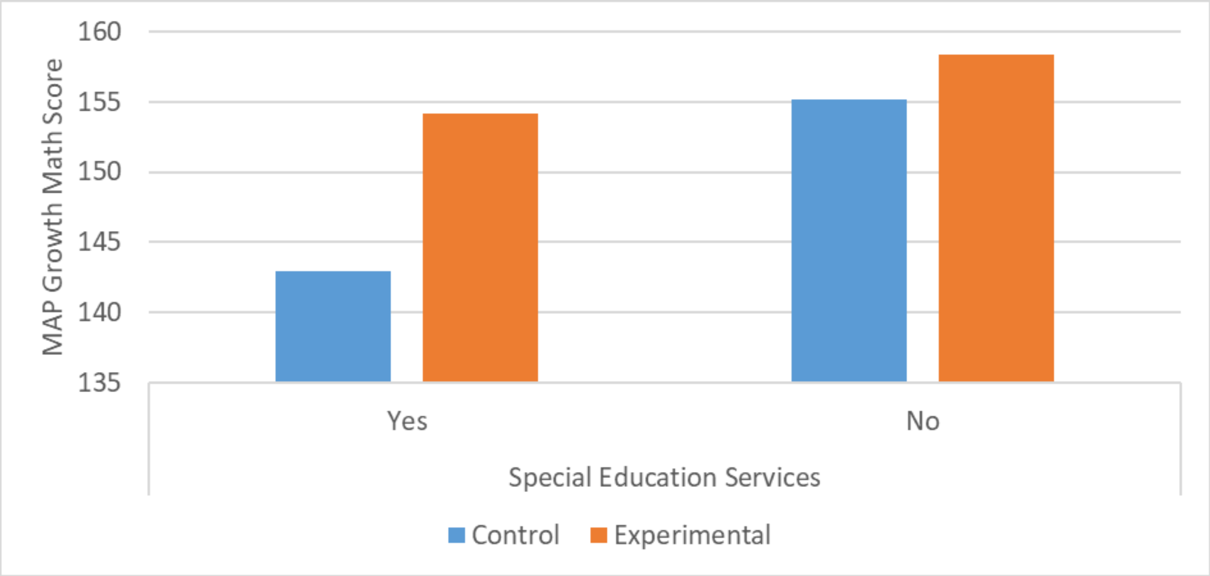


*Figure 6. Geometry end-of-year scores by special education services.*

## 4 CONCLUSIONS

Instilling early solid mathematical skills in students is essential for later learning success [2]; thus, high-quality, accessible, early learning interventions, such as CAI, are crucial. The results of the current study are consistent with previous findings that CAI can be an effective resource for enhancing young students' learning [10]. While students had similar math scores on average at the beginning of the year, students in the experimental group who used WRA to fidelity throughout the school year achieved higher math scores when assessed at the end of the school year compared to their control group counterparts. Overall effect sizes ranged from 0.25 to 0.38, indicating a meaningful effect across each measured subskill. These results proved to be consistent with the hypothesis, demonstrating that using CAI as a supplement to traditional classroom learning can positively impact students' mathematical outcomes.

Among the most important considerations when implementing a CAI program is that it benefits all students [12]. For students with special education services, mathematics has been an area of academic concern [7]. Findings from the current study support previous research that has shown CAI to be a suitable tool to help bridge this educational gap [13]. Results by special education services were strong, as scores for students with special education services were significantly higher in the experimental group than the control group for all subskills. All students in the experimental group achieved higher scores across all subskills compared to the control group, showing that all students benefited from using WRA. Overall, these results indicate that CAI had a meaningful impact on early mathematical skills across all the students in the sample.

One of the limitations of the current study is that students were only observed over the course of a single school year. Future research would benefit from following up with students one or more years after using the CAI software, measuring the degree to which this type of early mathematical instruction can impact students' later academic success.

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