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Journal of Research in Childhood Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ujrc20

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To cite this article: David J. Fleming & Brooke Culclasure (2024) Exploring Public Montessori Education: Equity and Achievement in South Carolina, Journal of Research in Childhood Education, 38:3, 459-484, DOI: 10.1080/02568543.2023.2283202

To link to this article: https://doi.org/10.1080/02568543.2023.2283202

JOURNAL OF RESEARCH IN CHILDHOOD EDUCATION
2024, VOL. 38, NO. 3, 459–484
https://doi.org/10.1080/02568543.2023.2283202

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Exploring Public Montessori Education: Equity and Achievement in South Carolina

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ABSTRACT

This article examines the expansion of public Montessori education and its implications for student participation and outcomes. The study focuses on the state of South Carolina, which has the largest number of public Montessori programs in the United States. Through a comprehensive analysis of demographic characteristics and standardized test scores, we investigate the participation of different student groups in public Montessori programs and compare the academic achievement of public Montessori students to their peers in traditional public schools. The findings indicate that public Montessori attracts a diverse range of students, but there is an underrepresentation of less-resourced students and students of color in public Montessori programs. Using matching procedures, we find that Montessori students demonstrated higher achievement growth in ELA and math compared to similar traditional public school students. Subgroup analyses find that higher achievement growth for Montessori students is consistent across many student groups. This study provides a comprehensive analysis of public Montessori and highlights the importance of considering curriculum and educational philosophy when evaluating the impact of education policies and programs.

ARTICLE HISTORY
Received 6 July 2023
Accepted 27 October 2023

KEYWORDS
Education segregation; equity; Montessori; school choice; student achievement

Montessori education has expanded throughout the world since 1907 when Maria Montessori opened her first school in Rome, Italy. In the United States, while students have participated in Montessori education for over a century, primarily in the private sector, Montessori has become one of the main alternatives to "traditional" education. At last count, there were estimated to be more than 570 public Montessori schools and 2,430 private Montessori schools in the United States (National Center for Montessori in the Public Sector [NCMPS], 2023). Currently, approximately one-eighth of all Montessori schools in the country claim some type of public status (magnet school, charter school, or district public school). Given the current expansion in the number of school choice options for parents in the United States, public Montessori schools will likely continue to grow in the coming years.

However, relatively little is known about the types of children who participate in Montessori programs. The Montessori method was originally designed for at-risk and special needs students before expanding to provide an alternative approach to education for all students (Montessori, 1912/1988). Further, Montessori education has historically been supported by a diverse group of parents and educators (Debs, 2019). However, some believe that Montessori is seen as an "elite" approach to education, as high-income or white students are often represented in Montessori programs (Brown, 2016; Debs, 2016). With the recent expansion of Montessori education into the public sector, there now is much greater availability of this type of education for students. Examining who participates in public Montessori programs can help us understand the relationship between Montessori education and educational segregation in public schools.

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Parents, school officials, policymakers, and researchers are also interested in a second important issue – how Montessori impacts student outcomes. Despite being an established method of education, the research base for Montessori is limited to small-scale evaluations. The question of the efficacy of Montessori is of particular interest in public Montessori programs, as these schools have standards and accountability requirements that can be inconsistent with the Montessori method (Fleming et al., 2023). Because of these inconsistencies, which will be discussed further below, whether Montessori can thrive in a standardized test-focused environment remains an open question.

This study focuses on South Carolina, the state with the largest number of public Montessori programs at the time of the study, from 2012–13 to 2015–16. Public Montessori first arrived in the state in 1993 through the entrepreneurial energies of a single kindergarten teacher. After receiving approval from the school district, the teacher worked to create a Montessori program for 3-, 4- and 5-year-olds in New Zion, SC. The program soon became an exemplar, and interested teachers and school officials came from across the state to observe her program. The spread of public Montessori across the state led the South Carolina Department of Education in 2010 to create the position of state Montessori Coordinator. Though that stand-alone position has since expired, South Carolina continues to lead the nation in total number of public Montessori programs (NCMPS, 2023).

This study proceeds in four parts. First, we briefly describe the Montessori model and review the existing research on who participates in Montessori programs and how Montessori education is related to student outcomes. Then, we outline our research questions, our data and variables, and our analytical approach, which relies on matching public Montessori students to students in traditional public schools. In the results section, we compare the demographic characteristics and standardized test scores of these Montessori students to other public school students. We examine whether public Montessori students differ from students across the state and within their districts. We then describe the achievement levels of Montessori students using standardized tests. We employ several different models to examine this question. We also consider the possibility that Montessori education may produce differential effects or may be more effective for some types of students versus others. Last, we consider the implications of our findings for researchers and policymakers.

Literature review

Developed by Dr. Maria Montessori to serve lower-resourced students in Italy, high-fidelity Montessori education is composed of several key components, including multiage groupings that foster peer learning, uninterrupted blocks of work time, and guided choice of work activities (Lillard, 2017). Additionally, the Montessori classroom experience includes carefully arranged, specific, hands-on Montessori learning materials, no extrinsic rewards or grades, and child-led exploration of personal learning interests while interacting with others in the environment (Lillard, 2017). The key components of Montessori education are illustrated in the Logic Model for Montessori Education (Culclasure et al., 2019).

While Dr. Montessori was originally invested in educating less-resourced children, as the Montessori model has since proliferated, many private Montessori programs have not been accessible to families and students from lower socioeconomic backgrounds. Still, Montessori education is a popular choice for families across racial and income groups (Debs, 2019; Parker, 2007), and parents who send their children to public Montessori programs value diversity as well as low educational cost, given there is no tuition for attendance (Zarybnisky, 2010). The growth of public Montessori programs following desegregation has shown promise in expanding who has access to these programs. In a study of public Montessori schools, Debs (2016) finds that these schools serve a higher proportion of students of color, particularly Black students, in comparison to U.S. public schools overall. However, these schools enroll fewer students of color and low-income students than their surrounding districts with public Montessori students tending to be slightly more economically advantaged than non-Montessori public school students (Debs, 2016). Other work also indicates that students of color and lower SES students are often

underrepresented in public Montessori programs (Debs & Brown, 2017). Nevertheless, public Montessori students, especially Black and Latinx children, are more likely to attend schools that are racially diverse in comparison to their public school peers (Debs, 2016). These selection effects are important as lower-resourced children and students of color have been shown to benefit from Montessori education in terms of students' academic skills and assessment scores (Ansari & Winsler, 2014, 2022; Brown & Lewis, 2017; Courtier et al., 2021; Debs & Brown, 2017; Hanson, 2009; Lillard et al., 2017; Tobin et al., 2015).

Over the past 20 years, researchers have evaluated the implementation of the Montessori method and subsequent outcomes from participation in both private and public Montessori programs (e.g., Ansari & Winsler, 2014; Byun et al., 2013; Demangeon et al., 2023; Dohrmann et al., 2007; Hanson, 2009; Lillard, 2012; Lillard & Else-Quest, 2006; Lillard et al., 2017; Lopata et al., 2005; Peng & Md-Yunus, 2014; Randolph et al., 2023; Rathunde & Csikszentmihalyi, 2005). Many of these previous studies have important limitations, including small samples, varying degrees of fidelity to the Montessori method, and selection bias. Because of these challenges and shortcomings, there is still a need for more rigorous research on Montessori implementation and outcomes for students.

The Montessori model and standardized testing requirements are seemingly incompatible (Fleming et al., 2023). Standardized tests contradict many of the key principles and practices of the Montessori method, while Montessori programs often facilitate learning environments that differ drastically from traditional public school models. Standardized tests may be unsuited for assessing Montessori student performance, with Montessori teachers and administrators noting the incompatibility of state grade level testing standards and 3-year multiage Montessori classes (Jacobson, 2007; Sparks, 2016). In an examination of a U.S. public Montessori school, Block (2015) observed that school administrators modified classroom methods, assessments, and curriculum in a manner that reduced adherence to the Montessori philosophy, primarily to align with government requirements. Additionally, some Montessori students may be unfamiliar with test assessments or the use of extrinsic rewards or scoring of their work. Some believe state-mandated proficiency tests are designed to benefit students in conventional education rather than students participating in non-traditional education such as Montessori (Hansen, 2021).

Despite these challenges, public Montessori programs must meet state testing standards. As policymakers, parents, and taxpayers are concerned with the standards and accountability of schools, it is important to measure the performance of Montessori programs in comparison to traditional public schools on these standard measurement tools. Still, previous research has demonstrated that Montessori students often perform just as well or better on standardized assessments as their non-Montessori counterparts (Ansari & Winsler, 2014, 2022; Brown & Lewis, 2017; Demangeon et al., 2023; Dohrmann et al., 2007; Hanson, 2009; Lillard & Else-Quest, 2006; Lillard et al., 2017; Lopata et al., 2005; Mallett, 2014; Manner, 2007; Peng & Md-Yunus, 2014; Randolph et al., 2023; Ruijs, 2017; Snyder et al., 2022). Montessori students may still score well on standardized tests, as foundational concepts of the Montessori model (e.g., child choice and interest motivating the activities they complete, working in multiage cohorts, and conveying concepts in meaningful contexts) can enhance early cognition and student learning (Lillard, 2017).

Previous work on Montessori student test performance has been conducted in a variety of contexts using several different research designs. Several studies have now leveraged school lotteries to conduct randomized control trials (RCTs) to study the outcomes of Montessori students (Lillard & Else-Quest, 2006; Lillard et al., 2017; Ruijs, 2017). In their study of public Montessori schools, Lillard and Else-Quest (2006) found that 5-year-old public Montessori students performed better on both math and reading standardized tests. Lillard et al. (2017) found that over time, students in two public Montessori schools performed better on measurements of academic achievement. Both studies suffer from relatively small sample sizes, Lillard and Else-Quest (2006) examined 59 Montessori students and Lillard et al. (2017) included 70 Montessori students. Ruijs (2017) also conducted an RCT in Dutch schools but found no difference in the academic achievement of Montessori versus non-Montessori students.

Overall, these results from RCTs suggest that Montessori education can increase student achievement, but questions about Montessori fidelity and small sample sizes of the studies threaten their external validity.

Other researchers have employed other techniques to compare the academic performance of Montessori and non-Montessori students. Dohrmann et al. (2007) conducted a study with 201 public school students, matching students who attended Montessori from preschool to 5th grade with non-Montessori students on gender, race, socioeconomic status, and which high school they attended. They found that the high school students who had attended Montessori schools performed better on math and science standardized tests, while there was no difference in English tests and overall GPA. Likewise, Ansari and Winsler (2022) found that low-income Latinx students who attended a public Montessori pre-K program had higher math and reading scores in 3rd grade in comparison to other low-income Latinx students who had attended a non-Montessori pre-K program. In another longitudinal study of public Montessori students, Mallett (2014) finds no difference in math and reading achievement for Montessori students in a 1st-grade cohort as they progressed through elementary and secondary schools. Mallett's (2014) study only included 86 students. Lopata et al. (2005) matched four public schools in New York based on gender, ethnicity, and SES composition, comparing 4th- and 8th-grade students in a Montessori school to students in two different charter schools and a traditional school. With mixed results from their analysis, they conclude there is no consistent pattern in math and ELA achievement to support the hypothesis that Montessori was associated with higher academic achievement. Similarly, Mallet and Schroeder (2015) found mixed results when examining the reading and math scores of 518 Montessori and 517 non-Montessori students in grades 1–5 in a Texas public school district. For students in 1st, 2nd, and 3rd grades, there was no significant difference in reading and math scores in the achievement of Montessori and non-Montessori students, but for grades 4 and 5, Montessori students performed better in both reading and math. Using 37 matched pairs of students based on previous math and reading performance, Manner (2007) compared standardized test scores of public elementary Montessori students to traditional public school students in a Florida school district, finding that over three years, Montessori students scored significantly better in reading and, while not significant, there was an increasing gap in the math achievement of Montessori and traditional school students.

More recent research by Snyder et al. (2022) identifies the 10 states with the most public Montessori schools to then evaluate Montessori schools' ELA and math standardized test performance in 3rd and 8th grade in comparison to the same or most geographically proximate district students. In a model controlling for the percentages of students historically affected by the racial opportunity gap and economically disadvantaged students, the researchers find that in 3rd grade, Montessori schools were less proficient in math but more proficient in ELA than the district at large; in 8th grade, however, Montessori schools had a greater percentage of students proficient in ELA and math although the difference was only significant for ELA. While this study provides a more expansive analysis of public Montessori programs than previous evaluations, it is limited by the fact that it is a school-level analysis, so the authors are unable to observe student-level growth.

Two recent meta-analyses also have been published that include many of the studies described above. In Demangeon et al. (2023), authors examined the effect of Montessori outcomes from 33 experimental or quasi-experimental studies comparing Montessori with other educational approaches. Results showed that Montessori's effects on development and learning were positive and varied from moderate to high, depending on the dimension considered (cognitive abilities, social skills, creativity, motor skills, and academic achievement). In the other, Randolph et al. (2023), authors included 32 studies to examine the effectiveness of Montessori education in improving academic and nonacademic outcomes compared to traditional education models. This analysis found evidence that Montessori education outperformed traditional education on a wide variety of academic and nonacademic outcomes (creativity, executive function, inner experience of school, and social skills). It is important to note that baseline equivalence was not considered in Demangeon et al. (2023), while it was considered in Randolph et al. (2023).

Given the growth in Montessori education, it is unsurprising that previous scholars have examined how Montessori participation is associated with student outcomes. While suggestive, many of these studies are unable to account for selection bias (e.g., Mallet & Schroeder, 2015; Manner, 2007; Snyder et al., 2022), have small sample sizes (e.g., Lillard & Else-Quest, 2006; Lillard et al., 2017), or focus on private Montessori (e.g., Peng & Md-Yunus, 2014). Additionally, very few of these studies were able to reliably establish fidelity to the model for those Montessori programs included in the outcomes analyses.

Method

The section below describes the study's research questions, participants in the research, measures, and analytical approach.

Research questions

Research Question 1: How do public Montessori students compare demographically to traditional public school students?

This is an important area of exploration, as there is a divide in the understanding of Montessori participation. As discussed above, the public image of Montessori as an elite approach to education is counter to the early history of Montessori. Further, a 2022 survey of parents found that Montessori has broad support across education levels and racial groups (Fleming, 2023).[1] Further, the issue of how school programs such as Montessori may affect the distribution of students in public schools is an area that needs greater attention, as few studies examine how a particular curriculum may attract parents. Most of the literature in this area examines who participates in various school choice programs without investigating how particular school curricula may affect parental participation.

Research Question 2: How does the academic achievement of public Montessori students compare to the achievement of traditional public school students?

Previous research, which has generally relied on small sample sizes, private school settings, or limited research designs, indicates that Montessori education may enhance student achievement. However, a more robust analysis that focuses on public Montessori students is needed. It is possible that the potential promise of Montessori education suggested by previous studies does not apply to public school settings because of implementation and accountability challenges in the public sector.

Participants

The dataset used in this study included all public school students from 2012–13 to 2015–16 in South Carolina. Importantly, this database had an indicator variable for students who received Montessori education in a given academic year. This allowed us to identify which specific students were learning in Montessori classrooms. To ensure that students who were identified as receiving Montessori education did so, we surveyed all principals who were thought to have a Montessori program. The survey asked about several of the components of Montessori implementation and fidelity. We worked to affirm that the Montessori schools included in the analysis were, in fact, Montessori schools with a minimum level of fidelity and not merely Montessori schools in name only. Thus, the Montessori programs included in this study include a range from low to high-fidelity Montessori programs. While this may attenuate our estimate of a Montessori effect on achievement, it is reflective of how Montessori programs operate in the public sector.

In addition to Montessori participation, the dataset also included variables pertaining to student race, gender, poverty status, disability status, English as a second language status, and grade level. We used these variables in our examination of who participates in public Montessori, as well as covariates in our student achievement analyses.

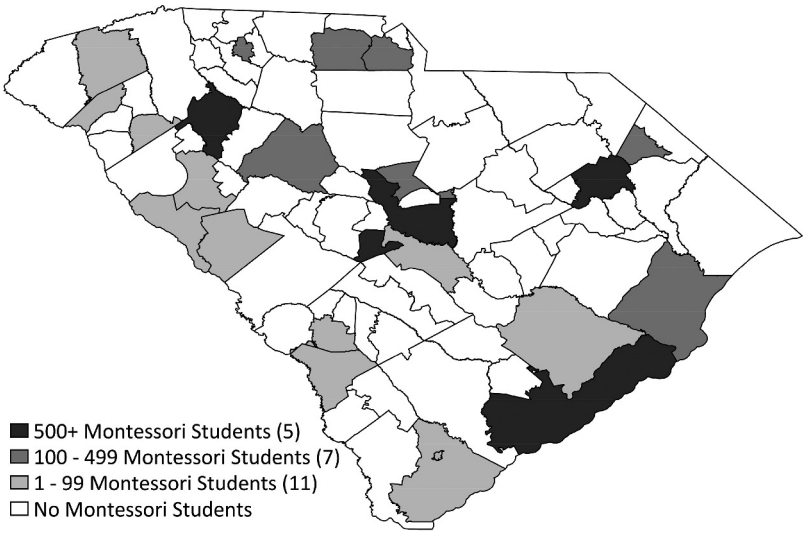

Figure 1. Public Montessori enrollment by school district. Note: This figure reflects the number of students enrolled in public Montessori programs in the academic year 2015-16 by South Carolina school district. The number of school districts for each level of Montessori enrollment is presented in parentheses.

As noted above, South Carolina is a leader in public Montessori programs. Using our dataset, we can see that participation in public Montessori is widespread and includes both rural and urban school districts. A map of the number of students who participated in public Montessori in 2015–16 by district is provided in Figure 1. Twenty-three school districts offered public Montessori; while 11 districts had fewer than 100 Montessori students, five districts enrolled over 500 public Montessori students in 2015–16.

During the years of our study, the number of public Montessori programs expanded in the state from 42 programs in 2012–13 to 44 in 2015–16 (see Table 1). South Carolina is unique not just in the number of public Montessori programs, but also in terms of the structure of the programs. Unlike many states, the vast majority of South Carolina's Montessori programs are district schools. Of the 44 programs in 2015–16, 2 were charter, 8 were magnet, and 34 were regular district schools. With the exception of one district in which Montessori is the only pre-kindergarten public option, parents must choose to enroll their children in a Montessori program. Most Montessori programs in South Carolina (68%) operate in the same buildings as traditional classrooms, which is similar to a school-within -a-school structure.

Table 1. Growth in South Carolina public Montessori participation.

	2012–13	2013–14	2014–15	2015–16
Programs	42	43	43	44
Total Enrollment	6,365	6,876	7,164	7,402
PK	1,587 (24.9%)	1,533 (22.3%)	1,383 (19.3%)	1,269 (17.1%)
K	1,062 (16.7%)	1,031 (15.0%)	1,078 (15.1%)	960 (13.0%)
1st	976 (15.3%)	1,034 (15.0%)	1,048 (14.6%)	1,177 (15.9%)
2nd	818 (12.9%)	953 (13.9%)	976 (13.6%)	1,042 (14.1%)
3rd	647 (10.2%)	747 (10.9%)	826 (11.5%)	891 (12.0%)
4th	538 (8.5%)	659 (9.6%)	706 (9.9%)	798 (10.8%)
5th	354 (5.6%)	479 (7.0%)	587 (8.2%)	596 (8.1%)
6th	171 (2.7%)	208 (3.0%)	287 (4.0%)	350 (4.7%)
7th	106 (1.7%)	126 (1.8%)	155 (2.2%)	187 (2.5%)
8th	106 (1.7%)	106 (1.5%)	118 (1.7%)	132 (1.8%)

This table presents the number of South Carolina public Montessori programs, total public Montessori student enrollment, and public Montessori enrollment by grade for the 2012–13 to 2015–16 academic years.

Growth in Montessori participation is also evident at the student level. The panel nature of our dataset allowed us to track students from 2012–13 to the 2015–16 school year. The number of public Montessori students in the state increased by over 1,000 students during the duration of our study. As of 2015–16, approximately 7,400 students participated in public Montessori in South Carolina. As public Montessori expanded in the state, participation increased among older students, as programs offered higher levels of Montessori as the students aged. Pre-kindergarten and kindergarten students made up 42% of all Montessori students in 2012–13 but only 30% of the Montessori population in 2015–16. A significant number of Montessori students, 2,954 or 40% of the total, were in grades 3 to 8 in 2015–16. This is important for this study, as only students in these grades took the state-mandated achievement tests.

Measures

Our outcome analyses focused on South Carolina public school students who were tested in grades 3–8 in ELA and math each year. They were also tested in writing in the first three years of the data before the state terminated the exam in 2015–16. The accountability regime changed in South Carolina, resulting in three different ELA and math academic achievement tests during the time period of this study: SCPASS (South Carolina Palmetto Assessment of State Standards); ACT Aspire; and the South Carolina College and Career Ready Assessments (S.C. Ready), the current statewide assessment. To create a common metric, we standardized the test scores by subject, year, and grade. These z-scores are in standard deviation units. A student with a standardized test score of 0 is at the 50th percentile in South Carolina in that subject in that grade and year.

Analytical approach

This study examined two main research questions. First, we investigated who participated in public Montessori programs. To answer this question, we explored the districts in which Montessori was offered and the demographic characteristics of Montessori students. To get a sense of how Montessori students compared to state averages, we used the South Carolina state database to provide an evaluation based on race, gender, poverty status, English as a second language status, and special education designation. This is largely a descriptive analysis. A more localized comparison was necessary, however, as only some districts offered public Montessori. Therefore, we also compared the demographic makeup of Montessori students to traditional public school (TPS) students in the same school district.

Our second research question asked how Montessori participation was related to student achievement, as measured by standardized test scores. We examined this question in several ways. First, we used coarsened exact matching (Iacus et al., 2012) to create a comparison group of traditional public school students that were as similar as possible to the Montessori students on demographic and baseline test scores. After providing the main matched results based on our pooled sample, we considered several different models and subgroups. We estimated year-by-year models and then considered the achievement growth of one cohort over the three years of outcome data. Lastly, we investigated the potential differential effects of Montessori education before examining some sensitivity analyses.

Evaluators of education policies must contend with many challenges. Of chief importance are internal and external validity. To estimate a causal effect, many evaluators will rely on randomized control trials (RCTs). This method has been used previously in Montessori evaluations by taking advantage of oversubscribed Montessori programs (e.g., Lillard & Else-Quest, 2006; Lillard et al., 2017). Given that the offer of participating in a Montessori program is random, the RCT approach allows one to estimate differences in outcomes while minimizing selection bias.

While the high internal validity of the RCT approach is certainly a strength, it often comes at the expense of external validity. A random lottery is often unavailable for education evaluations, such as in

our study. Further, when complete data on the implementation of a random lottery are available, it often creates situations in which the sample sizes in RCT evaluations are quite small, such as the small sample sizes in previous Montessori RCTs. In addition, those programs that are oversubscribed may be very different than the typical program. For example, previous research suggests that oversubscribed charter schools provide larger achievement gains than undersubscribed ones do (Ackerman & Egalite, 2017; Angrist et al., 2011; Betts & Hill, 2006). Therefore, RCTs may overestimate the "average" charter effect. Alternative methods, which include both schools with a waiting list and those without, should increase external validity (Ackerman & Egalite, 2017).

Matching methods provide an alternative approach to investigating the effects of Montessori education. While there are many different ways to implement matching procedures (e.g., Guo & Fraser, 2014), the basic approach is to match treatment to control subjects based on observable characteristics. Given proper covariate balance and other important assumptions, results from matching analyses have been found to replicate RCT findings in within-study comparisons (Angrist et al., 2011; Bifulco, 2012; Cook et al., 2008; Fortson et al., 2012; Shadish et al., 2008).

This evaluation employs a form of coarsened exact matching (Iacus et al., 2012) and synthetic control comparisons (Abadie et al., 2010), or what CREDO calls "virtual control records" (Center for Research on Education Outcomes Center for Research on Education Outcomes (CREDO), 2009, 2013, 2015).[2] This nonparametric method looks to create exact matches on categorical variables. For example, a white, low-income, female Montessori student who has a disability would be matched to TPS students who are also white, low-income, and female with a disability. Matching with continuous variables is more complicated, as "bins" are created to find suitable matches. After the matches are determined, researchers can then perform their analyses on the new sample (e.g., OLS regression or ANCOVA).

Our procedure first identifies each Montessori student in grades 4 to 8 from 2013–14 to 2015–16. Starting with the earliest data available, we then look to match each Montessori student to a TPS student from the same school district. This was done to improve internal validity and create better matches to produce samples of students that are more alike on both observed and unobserved dimensions, as students who live in the same district may share a host of similar characteristics.[3] Previous research has indicated the importance of "local matching" or matching within geographical locations (Cook et al., 2008). Bifulco (2012) uses a within-study comparison design and finds that matching within a district or demographically similar districts improves matching quality. If a TPS student ever participated in a Montessori program in the dataset, they are excluded as a possible comparison match.

After identifying TPS students in the same school district as the Montessori student, we exact matched on grade, gender, race (Hispanic, white, black, and other race), poverty status, ESL designation, and special education status. This means that the TPS pool for a Montessori student will have the exact same values for these characteristics. We then examined baseline test scores that were standardized by subject, year, and grade. Students were matched separately for the math, ELA, and writing analyses using the respective baseline test score (t-1).[4] This means that a Montessori student may have different TPS matches for the three subjects. Given that it would be very difficult to find sufficient matches if students were exact matched on baseline test scores, we used a different approach, which is consistent with coarsened exact matching. If TPS students' test scores differed from the Montessori student's score by more than 0.10 standard deviations, they were dropped from the possible match pool.[5] The inclusion of a baseline measure of the dependent variable in the matching process, especially in conjunction with local matching, can significantly reduce bias (Bifulco, 2012; Fortson et al., 2012).

We selected up to five TPS students who had the closest test scores to the Montessori student to be included in the analysis. Following the CREDO procedure, these five TPS students' scores were then averaged at baseline and going forward, creating a "virtual control record." There are two benefits of creating this composite score. First, it has less noise than a nearest-neighbor matching approach; second, it allows better comparisons between Montessori and non-Montessori over time

because if a TPS student subsequently drops out of the dataset, the TPS composite score can be recalculated without that student (Davis & Raymond, 2012, p. 227).[6] Montessori students stay in the analysis as long as they remain in a Montessori program.

Before we examine the test score outcomes, we provide three analyses to describe the results of this matching process. There could be multiple reasons why a Montessori student could not be matched. The student may be missing baseline demographic values or test scores; this is why the analysis begins with 4th-graders so that 3rd-grade test scores can be used as a baseline covariate. Further, a Montessori student would be unmatched if we could not find a suitable exact match on student characteristics and within 0.10 standard deviations on the baseline test. The types of students most likely to be unmatched for this reason are those with "unusual" combinations of characteristics and test scores for that particular grade and school district. If a match could not be found for a Montessori student, we attempted to find a suitable match in subsequent years, provided the student remained in a Montessori program. We first demonstrate the success of the match on observable characteristics in Table 2. Given the exact matching, it is unsurprising that the Montessori and TPS matched samples have exactly the same student characteristics. Despite matching within 0.10 standard deviations on test scores, one can see that the mean standardized test scores are very similar between the two groups. This is true of the students who were initially matched in 2013–14, as well as those matched at later periods.

Second, the bottom of Table 2 shows the percentage of students matched. As one can see, approximately 72% – 75% of Montessori students were matched depending on the analysis. By being able to include more students in the models, this matching procedure provides higher external validity than student fixed effects analyses (Davis & Raymond, 2012). The ELA and math matched samples include over 2,500 Montessori students and the same number of TPS virtual control students, giving this analysis a much larger sample size than previous Montessori evaluations. However, the generalizability of this study is limited by the types of students who are included in the analyses. They may not be representative of public Montessori students in South Carolina generally. To examine this issue, we compared the student characteristics and baseline test scores for those Montessori students who were matched and the Montessori students who were not matched. Table 3 shows that white and black students are overrepresented in the matched Montessori sample. This is unsurprising, as these racial groups are the most common in the districts included in the study, which allows for a greater pool of potential exact matches. The matched and unmatched Montessori groups are rather similar in poverty status and gender. Students with ESL or special education designations are underrepresented in the matched Montessori group, as are 4th-grade students. In terms of test scores, the average test

Table 2. Matching information: Demographics – Montessori matches vs. TPS students.

	ELA		Math		Writing	
	Montessori	TPS	Montessori	TPS	Montessori	TPS
Black	0.34	.34	0.33	.33	0.33	.33
Hispanic	0.03	.03	0.03	.03	0.03	.03
Other Race	0.03	.03	0.03	.03	0.02	.02
White	0.61	.61	0.61	.61	0.62	.62
Special Education	0.06	.06	0.06	.06	0.06	.06
ESL	0.02	.02	0.02	.02	0.02	.02
Poverty	0.50	.50	0.50	.50	0.50	.50
Female	0.51	.51	0.51	.51	0.51	.51
Baseline Test Score (2014 Match)	0.3299	.3297	0.0235	.0245	0.2376	.2379
Baseline Test Score (2015 Match)	0.1405	.1402	−0.0969	−.0976	0.1998	.2000
Baseline Test Score (2016 Match)	0.1089	.1090	0.0423	.0424		
N	2,504	2,504	2,561	2,561	1,771	1,771
% of Montessori Matched	72.20%		73.76%		74.82%	
Mean # of Matches	3.32		3.50		3.40	

This table presents the results from the coarsened exact matching algorithms for ELA, Math, and Writing. The matched public Montessori students are compared to matched TPS students. Students were also exact matched on grade, but the results for the grade matches are omitted from the table for space considerations. The demographic values reflect proportions of Montessori and TPS students, respectively, and the baseline test scores were standardized by grade, subject, and year.

Table 3. Montessori matched vs. Montessori unmatched comparisons.

	ELA		Math		Writing	
	Matched	Not Matched	Matched	Not Matched	Matched	Not Matched
N	2,504	964	2,561	911	1,771	596
White	0.61	0.50	0.61	0.49	0.62	0.46
Black	0.34	0.26	0.33	0.27	0.33	0.29
Hispanic	0.03	0.13	0.03	0.12	0.03	0.12
Other Race	0.03	0.11	0.03	0.11	0.02	0.13
Female	0.51	0.50	0.51	0.51	0.51	0.50
Low-income	0.51	0.51	0.50	0.55	0.50	0.51
ESL	0.02	0.09	0.02	0.09	0.02	0.09
Special Ed.	0.07	0.18	0.07	0.19	0.06	0.19
Grade 4	0.65	0.75	0.65	0.74	0.55	0.65
Grade 5	0.18	0.15	0.19	0.14	0.24	0.19
Grade 6	0.09	0.04	0.08	0.05	0.11	0.06
Grade 7	0.05	0.03	0.05	0.03	0.06	0.03
Grade 8	0.04	0.03	0.03	0.04	0.04	0.07
Test Score – 2013	0.27	−0.00	0.00	−0.04	0.23	0.31
Test Score – 2014	0.30	0.01	0.03	−0.02	0.28	0.29
Test Score – 2015	0.29	−0.00	0.12	0.13		

This table presents a comparison between the matched public Montessori students and the public Montessori students for whom no appropriate match could be found for the three matching algorithms (ELA, Math, and Writing). The demographic and grade rows reflect proportions, and the test scores were standardized by grade, subject, and year to have a median of zero.

scores in ELA are higher in the matched group than in the unmatched group, whereas the test score differences are smaller for math and writing.

Once the matched samples were constructed, we then estimated pooled OLS regressions. An advantage of this approach is that it is doubly robust, meaning that if either the matching process or the regression model is correct, then the causal estimates will be consistent (Ho et al., 2007). Both procedures do not have to be correctly specified to get consistent estimates. Our main analytic model is below:

$$Y_{i,t} = \theta Y_{i,t-1} + \beta M_{i,t} + \gamma X_{i,t} + \rho Y_i + \sigma C_i + \varepsilon_{i,t} \quad (1)$$

where the dependent variable is the standardized z-score value in math, reading, or writing for student, i, at time, t. This analysis focuses on growth rather than the level of achievement, so the baseline test score in the given subject is included as $Y_{i,t-1}$. β signifies the difference in achievement for Montessori and TPS students. $X_{i,t}$ is a vector of student characteristics that includes gender, race (black, Hispanic, or other race), ELS status, special education status, poverty indicator, and grade level. Y_i is the year fixed effect, and $C_i$is the cohort fixed effect, which indicates which cohort the student is in given when the student was matched. $\varepsilon_{i,t}$ is the error term, and the OLS regressions were estimated with robust standard errors.

It is important to reiterate that the identifying assumption of this methodology is that there are no unobservable factors that are related to the outcomes and participation in Montessori after students were matched based on district, student characteristics, and baseline test scores. If, after matching and adjusting for covariates in the regression, there are unobserved differences between the Montessori and TPS samples, then the results may be biased. This approach assumes that participation in Montessori is essentially random after the matching procedure. This assumption is not directly testable. However, after presenting our results, we do estimate how much selection bias would have to impact our study to substantively change our conclusions.

Results

This section proceeds in three parts. First, we examine student participation in South Carolina's public Montessori programs. We summarize the demographic characteristics of the public Montessori

students and compare them to non-Montessori public school students across the state and within the same school districts. Second, we provide a descriptive analysis of the academic achievement of public Montessori students as measured by standardized test scores. This analysis allows us to investigate the level of Montessori achievement compared to students across the state. In our third set of analyses, we compare public Montessori students to our matched sample of non-Montessori public school students. Year-to-year test score growth is examined, as is how multiple years of Montessori education are related to achievement growth. We also consider how the relationship between Montessori participation and test score growth may differ by student subgroup.

Participation in South Carolina's public Montessori programs

The first research question for this article concerns who participates in public Montessori. While some argue that high-income, white students are overrepresented in public Montessori schools (Debs, 2016), the Montessori method was initially created for at-risk students with disabilities (Lillard, 2017) and has broad appeal (Fleming, 2023). One way to examine this issue is to compare public Montessori students to non-Montessori, TPS students across the state (see Table 4). Table 4 includes each unique student observation in the South Carolina public school database from 2013–14 to 2015–16 in grades PK-8. Over this period, approximately 12,000 students participated in a public Montessori program. A majority of Montessori students, 54%, were considered low-income. However, given that 61% of students in the database across the state had a low-income designation, these students are somewhat underrepresented in Montessori programs. In terms of race, Montessori students generally reflect state averages. Students labeled as ESL are underrepresented in public Montessori programs, which could reflect where public Montessori programs are offered. Students who receive special education services are also less likely to participate in public Montessori; this could be due to the fact that their parents are less likely to enroll these students in Montessori programs or because public Montessori programs may be less likely to designate students as special education. Nonetheless, this analysis does not support the claim that public Montessori is only attractive to high SES or white parents.

While these comparisons are informative, they do not allow one to see how Montessori students may differ from other public school students in the same district. This is of particular importance, as not all districts have public Montessori programs, so not all public school students have the same amount of access to Montessori education. To examine this issue, we calculated the difference between the percentage of Montessori students who were white for each Montessori district and the percentage of traditional public school students in grades PK-8 in the same district who were white. Positive

Table 4. Demographic comparisons between South Carolina public Montessori and TPS students.

	Montessori	TPS
Low-income	0.54	.61
White	0.54	.51
Hispanic	0.06	.09
Black	0.35	.34
Other Race	0.05	.06
Female	0.51	.49
ESL	0.04	.07
Special Ed.	0.07	.10
N	11,815	1,026,866

This table presents demographic information for each public school student enrolled in grades PK-8 from 2013–14 to 2015–16. Students who were enrolled in public Montessori at any time during this time period are considered "Montessori," while those students who never attended a public Montessori school from 2013–14 to 2015–16 are labeled as "TPS." The demographic values reflect proportions of Montessori and TPS students, respectively.

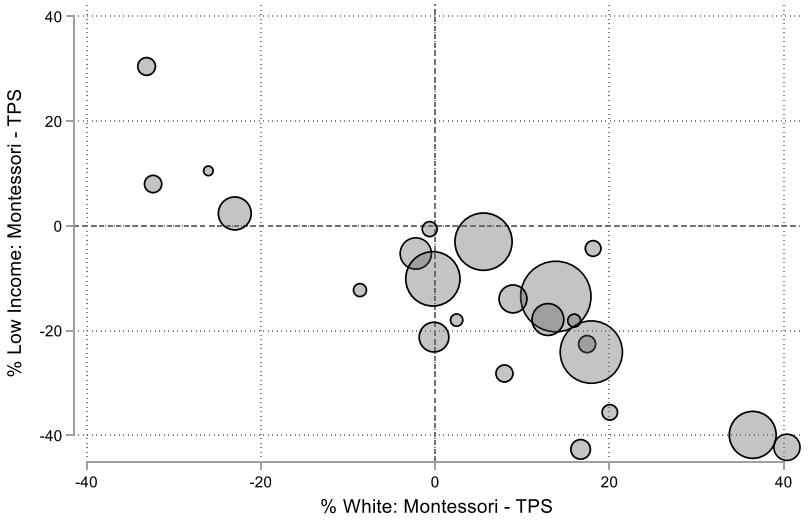

Figure 2. Public Montessori versus TPS student demographics by district. Note: This figure compares student race and family income of public Montessori school students to TPS students in the same school district. The y-axis is the percentage of public Montessori students who are low-income minus the percentage of TPS students who are low-income for each district that has public Montessori. The x-axis presents the percentage of public Montessori students who are white minus the percentage of TPS students who are white by district. Each circle in the figure represents a district that has public Montessori; the size of the circle reflects the size of the public Montessori enrollment in the district with larger enrollments equaling larger circles. The data used for this figure come from the 2015-16 academic year.

values indicate that white students are overrepresented in Montessori programs in that district, compared to other public school students in the district, whereas a negative value indicates that white students are underrepresented in public Montessori. We also performed a similar analysis using poverty status. These comparisons were made using the 2015–16 student data.

These two estimates are presented in Figure 2. Each circle represents a different school district, and the size of the circles reflects the number of students participating in Montessori in that district. Four districts are located in the upper left quadrant. Montessori students in these districts are more likely to be low-income and nonwhite than other public school students in the district. A handful of districts are near the center of the figure, indicating that Montessori students reflect the general public school population in those districts. A significant number of districts are in the lower right quadrant. In these districts, Montessori students are more likely to be white and non-low-income when compared to other students in the district. The size of the dissimilarity in some cases is very large, with differences of around 40% points.

This analysis provided some interesting conclusions. The majority of Montessori students are low-income, and approximately 45% are nonwhite. Public Montessori is not limited to high-income, white students in South Carolina. In general, the demographic makeup of public Montessori students in South Carolina is similar to the general public school population across the state. However, intra-district comparisons indicate that there is substantial variation between districts when comparing if Montessori participants mirror TPS students. Nonwhite and low-income students are generally underrepresented in Montessori programs. In the conclusion section below, we discuss some of the implications of this result.

Descriptive analysis of Montessori test scores

Given that the achievement performance of Montessori students remains an open question, we begin with a simple examination of the test scores of Montessori students. Table 5 presents the standardized test scores for Montessori students by year and subject. This analysis examines the level of achievement, not achievement growth, and includes all students with test data in the given academic year. The

Table 5. South Carolina public Montessori achievement by subject & year: Standardized scores.

	ELA		Math		Writing	
2012–13	0.284	(0.023)	0.061	(0.022)	0.306	(0.023)
2013–14	0.213	(0.020)	−0.032	(0.020)	0.228	(0.021)
2014–15	0.202	(0.020)	0.013	(0.019)	0.096	(0.019)
2015–16	0.205	(0.019)	−0.009	(0.019)		

This table presents test scores for public Montessori students in standard deviation units. The original scale scores were standardized by year, subject, and grade to have a median of zero. Standard errors are in parentheses.

test scores were standardized by year and grade level to have a median of zero. Looking at the ELA results, one sees that Montessori students consistently scored higher than the state averages. For example, in 2015–16, Montessori students had ELA test scores that were about .21 standard deviations above the median test score, adjusted for grade. The math results are more mixed, with Montessori students sometimes scoring above the median on average and sometimes below. Generally, the math results are near zero, or the 50th percentile. While Montessori students scored 0.31 standard deviations above the state grade-adjusted median in 2012–13 on the writing assessment, that advantage decreased to 0.10 by 2014–15. These results are merely a descriptive analysis and should not be interpreted as evidence that Montessori schools are more effective or lead to higher student achievement. While the results indicate a relatively high level of achievement for Montessori students in ELA and, to a lesser extent, writing, they do not allow us to examine student-level growth in learning from one year to the next. Our analyses below focus on growth, rather than levels of achievement, and compare public Montessori students to a matched sample of TPS students, rather than compared to all TPS students across the state, as in the analysis presented in Table 5.

Comparative analysis of Montessori and TPS test score performance

Our main results are presented in Table 6 from Equation 1 using the coarsened exact matching sample of Montessori and TPS students. Montessori students exhibit greater achievement in ELA and math when compared to matched TPS students, controlling for previous test scores and student characteristics. Montessori students also score higher than TPS students in writing, with a p-value for the Montessori indicator of 0.071. Although statistically significant, the Montessori coefficients are not large. Montessori students exhibited higher ELA achievement by 0.07 standard deviations. In terms of percentile change, this is equivalent to increasing a student's score from the median, or 50th percentile, to the 53rd percentile. The 0.06 standard deviation difference in math translates to a two percentile gain. These results also suggest lower achievement growth for black students when compared to white students, students with a special education designation, and low-income students. Given that the Montessori model may appear incompatible with the standards and accountability movement in U.S. public schools, it is important to examine the performance of public Montessori students on state standardized tests. These results indicate that when public Montessori students are compared to TPS students from the same district with the same student characteristics and similar baseline tests, Montessori students exhibit greater achievement growth, as measured by standardized tests.

These pooled regressions examine the year-to-year change in students' test scores. It is also possible that the relationship between Montessori participation and achievement may change by year. Previous results in Table 5 suggested that there was variation in Montessori achievement by year. To examine this possibility, we examined the three years of achievement growth individually. In our main analyses, we matched Montessori students to TPS students and followed them over time for as long as the Montessori student stayed in a Montessori program and the comparison students remained in the dataset. In the following analyses, we created new matches each year, using the previous year's test score as the baseline test score. We followed the same matching procedure as described above, exact matching on district, grade, and student demographics and matching test scores within a 0.10

Table 6. Main results – pooled regressions. Montessori vs. matched TPS achievement.

VARIABLES	(1) ELA	(2) Math	(3) Writing
Montessori Student	0.07***	0.06***	0.03*
	(0.01)	(0.01)	(0.02)
Baseline Test Score	0.69***	0.75***	0.54***
	(0.01)	(0.01)	(0.01)
Black	−0.12***	−0.11***	−0.08***
	(0.01)	(0.01)	(0.02)
Hispanic	0.00	0.07	0.01
	(0.06)	(0.06)	(0.12)
Other Race	0.05	0.03	0.01
	(0.04)	(0.04)	(0.08)
Special Education	−0.32***	−0.13***	−0.36***
	(0.03)	(0.03)	(0.04)
ESL	−0.08	−0.10	0.17
	(0.07)	(0.07)	(0.13)
Poverty	−0.22***	−0.18***	−0.17***
	(0.01)	(0.01)	(0.02)
Female	0.08***	−0.01	0.15***
	(0.01)	(0.01)	(0.02)
Constant	0.16***	0.10***	0.17***
	(0.02)	(0.02)	(0.02)
Observations	8,250	8,570	5,078
R-squared	0.67	0.64	0.47
Years	2014–2016	2014–2016	2014–2015

***$p < .01$, **$p < .05$, *$p < .1$ Robust standard errors are in parentheses. Grade, year, and cohort variables were also included in the analysis, but are omitted from the table for space considerations. The dependent variables, standardized test scores, are in standard deviation units.

bandwidth. The year-by-year results are presented in Table 7. The interpretation of the relationship between Montessori participation and student achievement over these years differs by subject. The ELA results are consistent with Montessori students scoring 0.07 to 0.08 standard deviations higher than TPS students. These were statistically significant ($p < .01$), although substantively modest, differences. In math, Montessori students exhibited higher math achievement growth in 2014–15 by 0.07 standard deviations ($p < .01$) and in 2015–16 by 0.05 standard deviations ($p < .05$). There were no differences in math achievement growth in 2013–14. While Montessori students had a 0.08 standard deviation advantage in writing in 2013–14, the difference between Montessori and TPS writing test scores was no longer statistically significant in 2014–15.

Table 7. Montessori regression coefficients by year and grade.

		ELA	Math	Writing
2013–14	Mont. Coeff.	0.08***	0.02	0.08***
	(S.E.)	(0.02)	(0.02)	(0.02)
	n	2,242	2,378	2,304
	% Matched	72.7%	77.2%	74.9%
2014–15	Mont. Coeff.	0.08***	0.07***	−0.01
	(S.E.)	(0.02)	(0.02)	(0.03)
	n	2,578	2,680	2,478
	% Matched	71.7%	74.4%	70.0%
2015–16	Mont. Coeff.	0.07***	0.05**	
	(S.E.)	(0.02)	(0.02)	
	n	2,858	2,946	
	% Matched	71.2%	73.3%	

***$p < .01$, **$p < .05$, *$p < .1$ Results from OLS regressions, including race, gender, poverty status, ESL, special education, grade, year, baseline test score, and cohort variables as covariates. The dependent variables, standardized test scores, are in standard deviation units. The percentage matched is the percentage of Montessori students with complete data who were matched.

The preceding two analyses focused on a one-year change in test scores; they do not allow us to investigate long-term Montessori effects on test scores or how multiple years of Montessori education may influence student achievement. To examine these issues, we focus on the 2014 Montessori cohort, the first cohort in our analysis. These Montessori students were matched to TSP students using the 2012–13 test scores and the algorithm described above. In the previous analyses, Montessori participation was determined on a year-to-year basis, and if a Montessori student transferred to a TPS, the Montessori student and their virtual control record match were subsequently removed from the analysis. Here, we take a different approach. In this analysis, Montessori participation was determined by Montessori enrollment in 2013–14. Then, Montessori students and their matches are followed over the next three years, even if the Montessori student transfers into a TPS. This approach is similar to an intent-to-treat analysis in an RCT, in which a student is assigned a treatment or control condition. That assignment designation follows the student even if the student no longer receives the treatment or the control condition. This is important in this case, as students may transfer from Montessori to TPS or vice versa for nonrandom reasons, which may not be captured by the covariates. This analysis assumes that the Montessori and matched TPS are identical at baseline; dropping students from the analysis for switching school types may upend the match.

The results of the 2014 cohort analysis are presented as a coefficient plot in Figure 3. The dots on the figure represent the Montessori coefficient from the OLS regressions with the usual covariates. The error bars signify the 95% confidence interval around the estimate. The first set of results indicates how Montessori students performed in ELA, math, and writing relative to the TPS matched group. One should note that these first results are identical to the 2013–14 results in Table 7. Again, Montessori students scored statistically significantly higher than TPS students in ELA and writing. The two-year growth results examine how the 2014 cohort's test results have changed from 2012–13, the baseline year, to 2014–15. Students who participated in public Montessori in 2013–14 exhibited greater achievement in two-year growth in both ELA and math than their virtual control records. There was no significant difference in writing after two years. Three years post-baseline, one sees that Montessori students have higher ELA test scores than matched TPS students by 0.16 standard

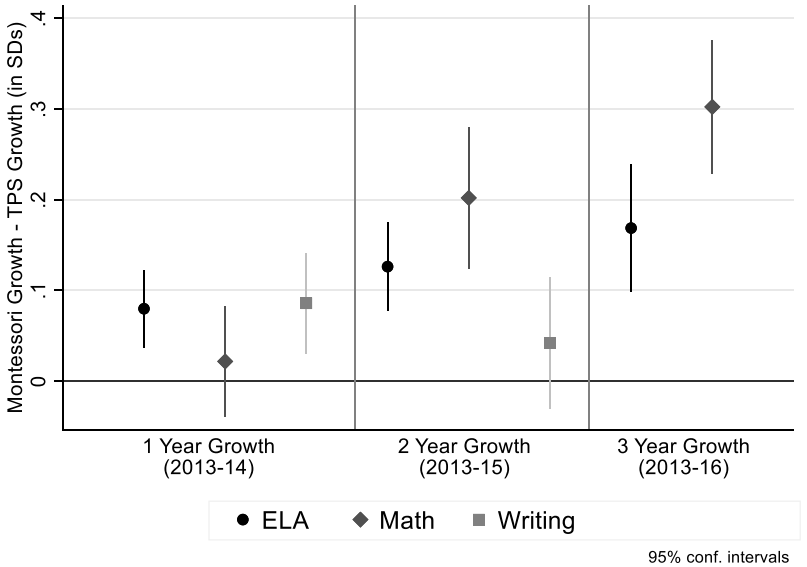

Figure 3. 2014 cohort analysis: Multi-year achievement growth. Note: Figure displays the Montessori estimate and 95% confidence intervals from OLS regressions that included race, gender, poverty status, ESL, special education, grade, and baseline test score variables as covariates. The dependent variables were the standardized test scores in standard deviation units from 2013-14, 2014-15, and 2015-16, respectively. Montessori participation was determined at baseline (2012-13). Estimates above the zero line indicate that Montessori students experienced more growth from baseline (2012-13) in that subject in that year than did TPS students.

deviations. The ELA effect size translates to a six percentile gain at the median. The Montessori advantage is 0.30 standard deviations in math, which means that students scoring at the 50th percentile in math achievement growth would be predicted to score in the 62nd percentile if they participated in Montessori education at baseline.

These results suggest that extended Montessori participation may be related to increased student achievement. However, given that Montessori participation was determined at baseline, it is possible that those Montessori students who transferred into a TPS after one year may be driving these Montessori results. To examine this possibility, we replaced the Montessori indicator variable with a vector of variables in the regression that represent the number of years the student participated in a public Montessori program from 2013–14 to 2015–16 for math and ELA and from 2013–14 to 2014–15 for writing. Given that students may transfer schools and programs for several nonrandom reasons, we consider these results suggestive rather than exact estimates of the causal effects of how participating in Montessori programs differs by the dosage or exposure to Montessori. The first OLS model in Table 8 predicted 2015–16 ELA test scores given how many years a student participated in Montessori and our usual covariates. The Montessori coefficients are in comparison to the matched TPS students who have zero years of Montessori experience. For the ELA results, approximately 32% of Montessori students had one year of Montessori, 33% had two years, and 35% were Montessori for all three years. One sees that all three levels of Montessori participation are associated with positive impacts over TPS students. The results are not limited to students who soon transferred into TPS, nor do they seem to grow with greater experience in Montessori. The results are similar for math, although the effect sizes are significantly larger. Looking at two years of writing growth, one sees that those students who had one year of Montessori scored significantly higher than the TPS matched students, whereas those with two years did not.

This analysis presented in Table 8 is limited by the fact we are only able to examine three years of student growth. When looking at the three-year growth estimates, only students who were in grades 4 through 6 at baseline are included, as older students graduated out of the analysis. Further, since Montessori is more common in the earlier grades than late middle school, Montessori effects will primarily reflect these early grades.

Our last examination of these data examines the possibility of subgroup effects. As described above, the Montessori model began with low-income students in Italy. Today, Montessori education is often associated with a higher-income or white student population. This analysis examines if Montessori education may be associated with higher levels of achievement for different types of students. We estimated these differences with a set of interaction models. These analyses use the pooled regression approach, similar to Equation 1. However, in these models, the Montessori variable was interacted separately with poverty status, race, gender, and baseline test score. After running these regressions, we

Table 8. Analysis of 2015–16 test scores by years in Montessori (2014 cohort).

	ELA (2016)	Math (2016)	Writing (2015)
1 Year of Montessori	0.11***	0.24***	0.11**
	(0.04)	(0.05)	(0.05)
2 Years of Montessori	0.21***	0.40***	0.03
	(0.04)	(0.04)	(0.04)
3 Years of Montessori	0.18***	0.26***	
	(0.03)	(0.03)	
N	1,780	1,916	2,070

***$p < .01$, **$p < .05$, *$p < .1$. Results are coefficient estimates from OLS regressions that compared the relationship between one, two, or three years of Montessori education to matched TPS students who had zero years of Montessori education. The regressions included baseline test score, race, gender, poverty status, ESL, special education, grade, year, and cohort variables as covariates. Robust standard errors are in parentheses. The dependent variables were standardized test scores in standard deviation units in 2014–15 (Writing) and 2015–16 (ELA, Math). Montessori participation was determined at baseline (2012–13).

used Stata's margins command to estimate the marginal effect on test scores of Montessori participation within each subgroup.

In Table 6, we found that, overall, there is an association between Montessori participation and ELA growth. How might the difference between Montessori and matched TPS students differ by subgroup? Plots of the marginal effect differences are presented in Figure 4. Looking at both low-income and non-low-income students, one sees that Montessori students score higher than similar TPS students, as the 95% confidence intervals do not intersect with the 0 line. While the marginal effects estimates by race are rather consistent, only Black and White Montessori students demonstrate significantly higher growth. One reason for this could be the relatively smaller sample sizes for Hispanics and those in the "other race" category, which produces larger confidence intervals. Both male and female Montessori students exhibit greater ELA growth than male and female TPS students. Finally, we compared students by baseline test score quintiles. Perhaps only the Montessori students who are highest performing or lowest performing at baseline exhibited higher growth. We found that Montessori students in each of the bottom four quintiles had higher ELA growth than similar TPS students; only those Montessori students at the 80th percentile or higher on the baseline ELA exam did not have a significantly higher ELA test scores than similar high-achieving students at baseline TPS students.

The subgroup analyses for math show that the average marginal effects of Montessori participation show positive growth for low-income, higher-income, white, male, and female students (see Figure 5). While Montessori participation does not produce significant marginal effects for students at the lower end of the baseline math distribution, for those who had higher baseline test scores, Montessori students had higher math achievement than their TPS counterparts. Lastly, the average marginal effects of Montessori participation for different subgroups are quite small in writing, as seen in Figure 6. Note that the overall Montessori advantage in writing was a modest 0.03 standard deviations. Montessori writing growth statistically significantly outpaces TPS growth for only two subgroups, females and those with baseline scores in the 3rd quintile.

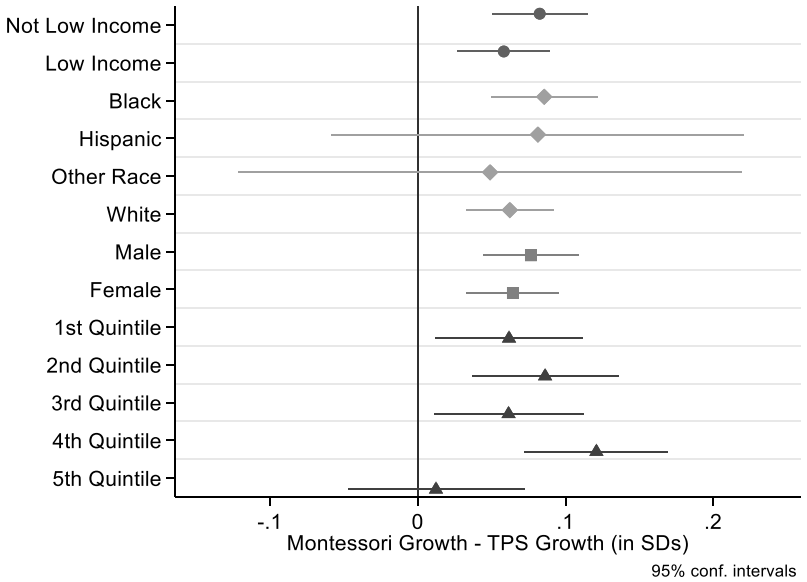

Figure 4. ELA subgroup analyses. Note: Figure represents the average marginal effect of Montessori participation by subgroup and 95% confidence intervals. The Montessori indicator variable was interacted with poverty status, race, gender, and baseline test score quintile. Pooled OLS regressions included race, gender, poverty status, ESL, special education, grade, year, cohort, and baseline test score variables as covariates. Positive estimates indicate that Montessori students in a given subgroup experienced more growth in ELA test scores than matched TPS students in the same subgroup. The dependent variables, standardized test scores, are in standard deviation units.

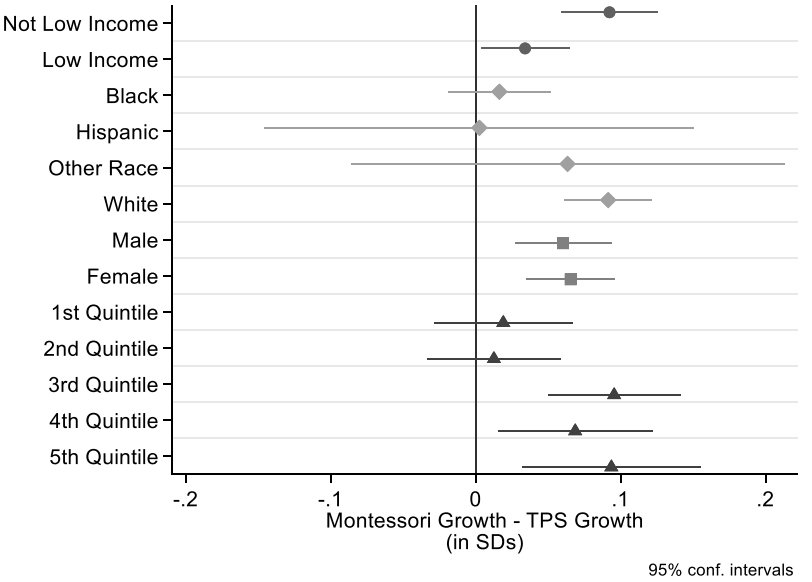

Figure 5. Math subgroup analyses. Note: Figure represents the average marginal effect of Montessori participation by subgroup and 95% confidence intervals. The Montessori indicator variable was interacted with poverty status, race, gender, and baseline test score quintile. Pooled OLS regressions included race, gender, poverty status, ESL, special education, grade, year, cohort, and baseline test score variables as covariates. Positive estimates indicate that Montessori students in a given subgroup experienced more growth in Math test scores than matched TPS students in the same subgroup. The dependent variables, standardized test scores, are in standard deviation units.

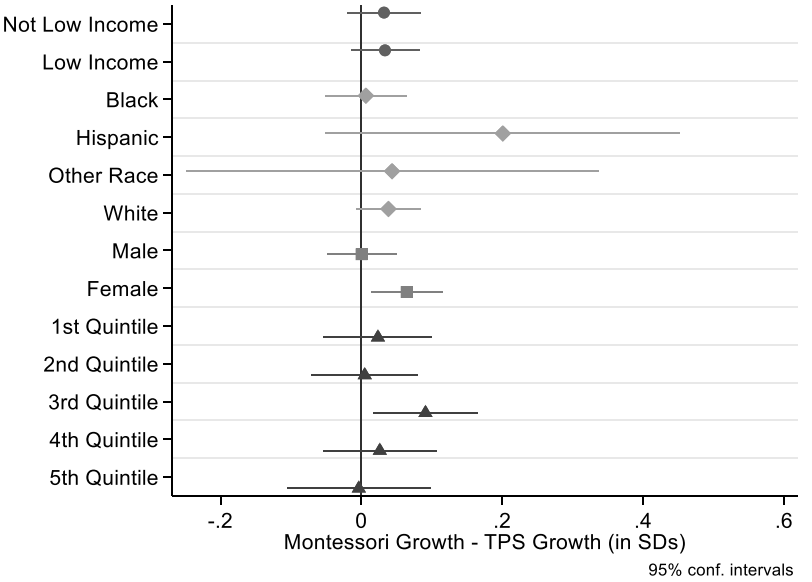

Figure 6. Writing subgroup analyses. Note: Figure represents the average marginal effect of Montessori participation by subgroup and 95% confidence intervals. The Montessori indicator variable was interacted with poverty status, race, gender, and baseline test score quintile. Pooled OLS regressions included race, gender, poverty status, ESL, special education, grade, year, cohort, and baseline test score variables as covariates. Positive estimates indicate that Montessori students in a given subgroup experienced more growth in Writing test scores than matched TPS students in the same subgroup. Negative estimates indicate that TPS students exhibited greater growth in Writing scores than did Montessori students. The dependent variables, standardized test scores, are in standard deviation units.

These analyses suggest that Montessori education may be broadly effective across different subgroups. This was particularly true for the ELA analyses. At least for the students included in these matched analyses, it seems like the egalitarian promise of the Montessori model may ring true, as the Montessori advantage was generally consistent across many different groups. However, it should again be emphasized that, like the main pooled analyses, the effect sizes for these average marginal effects are relatively modest, often between 0.05 and 0.10 for one year of growth.

Robustness checks and sensitivity analyses

The coarsened exact matching methodology employed in this evaluation assumes that there are no unobserved factors that are related to both the likelihood of participating in Montessori schools and our outcomes of interest. This type of self-selection or selection bias is a threat to the internal validity of this study. Previous evaluations have recommended using local matching or matching within similar geographical locations in hopes of minimizing this type of bias (Bifulco, 2012; Cook et al., 2008; Fortson et al., 2012). In our study, this was done via matching within school districts. However, other studies have restricted the matching pool even more by limiting potential matches to students who have attended the same feeder schools as treatment students. Given that many Montessori programs operate inside of a traditional public school setting, we can go a step further and match within the school.[7] Ideally, this method would account for several unobserved and observed characteristics, as students would share school and often neighborhood contexts. Besides limiting potential matches to those who attended the same school, we followed the same matching protocol as described above by exact matching on grade and student characteristics and limiting matches to TPS students within a test score bandwidth of 0.10 standard deviations. The standard errors in the OLS regressions were clustered by school.

The results from these pooled regressions are very similar to our main result for the ELA analysis. We find that Montessori students exhibited 0.07 standard deviations (s.e. = 0.03, p-value = .041) greater growth in ELA than within-school matched TPS students. Similarly, Montessori achievement in math exceeded matched TPS growth by 0.07 standard deviations (s.e. = 0.04, p-value = .096). Finally, while the Montessori coefficient is positive for writing growth (0.05, s.e. = 0.05), the relationship is not statistically significant (p-value = .285).

This robustness check was meant to improve the Montessori-TPS matches by matching within school. Ideally, this would account for important unobservable factors in the analysis. There are two large drawbacks to this additional analysis. First, there is a tradeoff between internal and external validity. Given that Montessori matches were limited to within-school TPS students, it was much more difficult to identify appropriate matches given the need to exact match on race, poverty status, ESL, gender, special education, and grade, as well as within a 0.10 standard deviation test score bandwidth. For the ELA analysis, 661 or 28% of Montessori students were matched. Approximately 34%, or 790 students, were matched for the math analysis and 454 (29%) for the writing regression.[8] The second main limitation of this robustness check is that our efforts to decrease selection bias may, in fact, have increased it. Hoxby and Murarka (2008) write, "By focusing on families who appear identical on observable variables but who make different schooling choices, we automatically focus on a sample of families who are disproportionality *un*alike on unobservable variables" (p. 16, emphasis in the original). However, given that the results from the within-school analysis are largely consistent with our within-district matching results, we have greater confidence in our conclusions regarding the relationship between Montessori participation and student achievement.

Given that selection bias may be unobserved, one is unable to estimate precisely how it may be affecting the relationship between Montessori participation and test scores estimated in this study. However, we can examine what percentage of the estimated effect must be due to bias to invalidate the inference of a relationship between Montessori participation and achievement growth (i.e., to no longer have a statistically significant result) (Frank, 2014). Following Frank et al. (2013), we applied this method to our main results presented in Table 6. Using the Montessori coefficient (0.07) and

standard error (0.01) for the ELA test analysis in Table 6 and assuming an alpha level of 0.05, we estimate that 67% of the estimated effect would have to be due to bias to invalidate the inference that there is a statistically significant relationship between Montessori status and ELA growth. This means that 68% (5,610) of the cases would have to be replaced with cases for which there is an effect of zero to conclude that there is no statistically significant relationship between Montessori participation and ELA achievement at the $p < .05$ level. Alternatively, to invalidate the inference, an omitted variable would have to be correlated at 0.216 with Montessori status and at 0.216 with the outcome, conditional on the covariates.

In our main analyses, we find that Montessori students score 0.06 standard deviations above matched TPS students in math. Following Frank (2014), we estimate that to invalidate the inference that there is a statistically significant relationship (at $p < .05$) between Montessori status and math growth, 64% of the estimated effect would have to be due to bias. To invalidate our conclusion that there was a statistically significant relationship between Montessori participation and writing growth at the $p < .10$ level, 9% of the estimated effect would have to be due to bias. Given that this type of sensitivity analysis is still rare in the literature, it can be helpful to provide comparison cases. Frank et al. (2013) apply these methods to 11 published quasi-experimental evaluations and find that the bias necessary to invalidate them ranges from 2% to 60% with a median of 28%. Our results compare favorably to these other studies.

Conclusion and discussion

We examined two main research questions in this study. First, we were interested in who participates in public Montessori programs. We found that Montessori participants are demographically quite similar to state averages. Large proportions of less-resourced students and students of color participate in public Montessori programs. However, when compared to TPS students in the same districts, low-income students and students of color are underrepresented in most Montessori programs. Who participates in choice programs has been an important topic of interest to evaluators (e.g., Fleming et al., 2015; Ladd et al., 2017). Parental schooling decisions have important implications for evaluating the "effectiveness" of different programs and policies and can impact the outcomes of students who do not participate in choice programs. One interpretation of our results is that Montessori programs may increase education segregation, as white and higher-income students are overrepresented in some programs. The finding that high-income parents are more likely to participate in a public school choice program is consistent with previous research (Debs, 2016). Montessori programs may affect public school participation in another way, as well. Given the popularity of Montessori education in the private sector, public Montessori programs may be drawing parents into the public sector. While complicating discussions of intra-district segregation, this phenomenon would increase the proportion of high-income and white parents within South Carolina public schools. Unfortunately, we are unable to test these various possibilities; however, future researchers should take a more nuanced look at how choice programs may affect not only segregation within public schools but also who participates in public schooling in the first place.

We then presented information on the achievement of Montessori students. We found that Montessori students generally score above the state averages in ELA and writing, while the results were mixed for math. To get a better sense of the relationship between Montessori participation and academic achievement, we implemented a coarsened exact matching procedure. In our main analyses, we matched each Montessori student to TPS students with the same district, grade, gender, race, poverty status, ESL designation, special education status, and within a 0.10 standard deviation test bandwidth. Analyzing these matched samples, we found that Montessori students demonstrated higher achievement growth in ELA and math, while the Montessori advantage in writing was more tenuous. We then examined some auxiliary analyses. While there were some differences in year-by-year results, Montessori students consistently demonstrated higher ELA growth than matched comparison students. There was no statistically significant advantage for matched TPS students in any of

the analyses. When examining outcomes multiple years from baseline, we found that Montessori students in the 2014 cohort scored substantively above matched TPS students after three years. Additional analyses demonstrated that the number of years participating in Montessori is associated with achievement gains.

While the overall relationship between Montessori participation and student achievement is important, we wanted to examine the possibility that the effectiveness of Montessori education could differ by subgroup. Our subgroup analyses demonstrated that the relationship between Montessori education and test scores in comparison to similar, matched TPS students is rather consistent across student characteristics in ELA and in math to a lesser extent. The benefits of Montessori education were not limited to higher income or white students. The equity implications of these results are crucial. Students from less-resourced families demonstrated greater ELA and math achievement growth than similar TPS students. Further, Black public Montessori students also had higher ELA growth than matched Black TPS students. Finally, there was a Montessori advantage for male students in ELA and math and for female students in all three subjects. While public Montessori alone would not eliminate all achievement gaps, our findings suggest that many diverse student populations could benefit from experiencing Montessori education.

Researchers have spilled a lot of ink trying to estimate the effects of school choice programs. These evaluations have often noted the high amount of variation in school and student performance and have called for investigations of the "black box." This evaluation examines one approach and curriculum that is implemented in traditional public, public schools of choice, and private schools. One reason for the mixed results of school choice evaluations may be the diversity of curricula and approaches offered in these schools. Researchers should not only examine who participates in school choice programs and if these programs increase test scores, but they should also consider how school curriculum or philosophy may influence parental choice and student outcomes.

Selection bias remains a threat to the validity of this study. The higher levels of Montessori achievement may be simply artifacts of who participates in Montessori programs. In the absence of a random lottery, we are unable to account for all possible confounders. We try to deal with the challenge in several ways. Our matching procedure created samples that were exactly the same in terms of student demographics. We used local matching to take geographic factors into account, and we relied on baseline test scores to adjust for previous academic achievement and related family and student factors. While we are unable to ensure that all self-selection is accounted for, previous evaluations of the method we employ have suggested that it has high internal validity (e.g., Ackerman & Egalite, 2017; Davis & Raymond, 2012; Fortson et al., 2012). Even if one is unconvinced that we can estimate a causal effect of Montessori education, we believe that the descriptive information on the achievement of public Montessori students is of great importance, as school officials, parents, and policymakers want to know if students who participate in public Montessori programs can perform at a high level on state-mandated standardized tests, especially given the incongruity between the philosophy of Montessori education and standardized testing.

There are also various reasons why this study may be underestimating the relationship between Montessori participation and achievement growth. Our growth analyses cover grades 4 through 8. Students were matched based on the prior year's test scores. For some Montessori students, the prior year's test score could come after many years in a Montessori program. If Montessori programs increase student test scores above what would be expected, students in Montessori programs would be matched with "intrinsically stronger" TPS students (Betts & Tang, 2014, p. 50). This may depress any observable Montessori effect in later years. This challenge may be particularly acute for Montessori programs, as they are often targeted at younger grades. Perhaps Montessori is the most effective for younger students, something we are unable to capture. Further, many public Montessori schools are new or growing. Previous research on charter schools indicates that new charter schools are often less effective than more established ones (e.g., Baude et al., 2014; Hanushek et al., 2007; Ladd et al., 2017). This implies that Montessori school performance may be even higher now, given that the programs are more established. While this

is a possibility, our analyses find little evidence that Montessori student performance consistently improved over the three years of the study. Lastly, the fact that we used state-mandated accountability exams to measure student achievement may lead to an underestimate of achievement growth for Montessori students. Standardized tests are antithetical to the Montessori model, and there may be tension between the state standards and the typical Montessori curriculum (Fleming et al., 2023). For these reasons, Montessori education may increase student learning in a way that is not reflected in higher standardized test scores. All these factors pose significant challenges in estimating the true relationship between Montessori participation and student achievement.

While our results indicated that Montessori students exhibited statistically significant greater achievement growth in many models, the effect sizes were often modest. Ackerman and Egalite (2017) note that evaluations from quasi-experimental design (QED) evaluations of charter schools often produce smaller effect sizes and more mixed results than results from RCTs. One explanation for the different conclusions from QEDs and RCTs is that selection bias affects the quasi-experimental results. Another possibility is that the type of schools that participate in RCTs through oversubscription lotteries may be particularly effective and popular. Previous research indicates that this is often the case (e.g., Abdulkadiroglu et al., 2009; Ackerman & Egalite, 2017). Our matching method includes a great diversity of Montessori schools. The effects that we see may be more generalizable than those from previous Montessori RCTs (e.g., Lillard & Else-Quest, 2006; Lillard et al., 2017). These analyses rely on oversubscribed schools and small samples. Further, they have a much higher bar of fidelity. In this study, we include 44 different programs with varying levels of fidelity to the Montessori model. This evaluation examines how Montessori education operates in the "real world" public sector. We hope that our matching method can produce the greatest combination of both internal and external validity.

We believe that this analysis provides an important contribution to the field. As Montessori programs expand into the public sector, it is crucial to analyze who participates in these programs and what their outcomes might be. Previous research is limited on both of these topics. Much of the work done in this area has taken place in private rather than public schools. Further, studies have generally been limited in sample size and only include students at the early childhood or lower elementary levels. In addition, our study includes a wide sample of Montessori programs. These programs range from urban to rural locations and have differing levels of fidelity to the Montessori model. We believe that our expansive study provides a more representative analysis of how Montessori programs operate in public school settings.

This study provides much-needed information on Montessori education. This is the largest evaluation of Montessori education to date. Given the selection issues associated with private education, studies of public Montessori programs provide the opportunity to examine a much more diverse student body. With almost 12,000 students participating in public Montessori programs in districts across the state during our study, South Carolina is an ideal environment for such an evaluation. This evaluation examines the presence and performance of public Montessori programs in South Carolina. Although Montessori education has existed for over 100 years, it is relatively new in the public sector. Given Montessori's emphasis on student self-direction, creative choices in learning, and intrinsic motivation, it is unclear how successful this approach can be in public schools, as the standards and accountability movement seems antithetical to the Montessori Model. Our results suggest that the Montessori method is popular with a diverse set of parents, and Montessori students exhibit achievement growth above or on par with similar TPS students. Despite the challenges of implementing the Montessori model in a public school setting, this evaluation suggests that Montessori schools have promise in the public sector.

Notes

1. Fleming's (2023) analysis suggests that the underenrollment of students of color and students from less-resourced families in Montessori programs could be partly explained by differential knowledge levels about Montessori. For example, Black parents were the most supportive racial group of Montessori education after becoming knowledgeable about it.

2. While the CREDO analyses use a method similar to coarsened exact matching, they do not cite the literature on this approach. See Gaertner and Kirshner (2017).
3. The CREDO evaluations and other studies (Ackerman & Egalite, 2017; Fortson et al., 2012) have gone even further and have limited the comparison pool to students who attended the same feeder schools that treatment students attended before enrolling in their treatment schools. However, Hoxby and Murarka (2008) contend that using students from baseline feeder schools may actually enhance selection bias as those who attended the same feeder schools but choose different schools at the next level are doing so for nonrandom reasons and are fundamentally different types of students. In their within-study comparison, Fortson et al. (2012) find that using the school district, rather than feeder schools, as a limiting characteristic when creating the possible matched pools does not substantively change the estimated causal effect. Therefore, we chose a middle ground and matched within district. We reexamine this decision as a robustness check later in this study.
4. Our analysis uses the baseline test score (t-1) for matching purposes. Unlike RCT designs in which students are assigned to conditions before experiencing Montessori education, our design does not allow for such comparisons. For example, Montessori students may have already experienced many years in Montessori before they are matched to non-Montessori students, which may attenuate any effect of Montessori. We thank a reviewer for highlighting this fact.
5. Critiquing the CREDO method, Hoxby (2009) cautions that this 0.10 bandwidth is too large, especially for students with extreme test scores. Fortson et al. (2012) examine this issue. They compare coarsened exact matching methods with 0.10 and 0.05 bandwidths and find no substantive difference in estimated charter school impacts.
6. While critics argue that this creates an unequal distribution of measurement error (Hoxby, 2009), an independent analysis found that using the CREDO procedure to match one-to-one or up to one-to-seven created estimated effects within 0.003 standard deviations and standard errors within 0.001 (Ackerman & Egalite, 2017).
7. The number of Montessori programs within TPS that are included in these analyses ranges from 22 programs in 2013–14 to 30 in 2015–16.
8. In an effort to relax the matching criteria, additional within-school matches were conducted that increased the test bandwidth to 0.20 standard deviations. Using this sample, the results for ELA, Math, and Writing are substantively similar to the results for the matching with the 0.10 bandwidth. Using the 0.20 standard deviation bandwidth matching sample, we find that the Montessori coefficient is 0.07 for ELA (s.e.: 0.04, p-value: 0.06), 0.08 for Math (s.e.: 0.04, p-value: 0.08), and 0.07 for Writing (s.e.: 0.05, p-value: 0.12). This more liberal approach produced samples in which between 42% – 47% of Montessori students were matched. Full results are available from the authors upon request.

Acknowledgments

The authors thank Mattie MacDonald and Shekinah Lightner for their research assistance on this paper. The authors acknowledge Gina Riga for her advice on this project. This article was produced as part of a larger evaluation of Montessori: Culclasure, B., Fleming, D. J., Riga, G., & Sprogis, A. (2018). *An evaluation of Montessori education in South Carolina's public schools*. The Riley Institute at Furman University. https://riley.furman.edu/sites/default/files/docs/MontessoriOverallResultsFINAL.pdf.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This project was funded by a grant from the Self Family Foundation.

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