The Effects of Digital Curriculum in the Classroom:
Rigorous Evidence from Three Digital Math Programs
Symposium Justification
SREE 2018 Spring Conference

Digital curriculum programs in U.S. public schools have come a long way since the occasional opportunity to play *Lemonade Stand* or *Oregon Trail* in the school computer lab of the 1980s. By 2009, schools had one computer for every five students, on average, and 97% of teachers reported having at least one computer in their classroom (Gray, 2010). Now, U.S. public schools spend more than $3 billion per year on digital content (Herold, 2016), and digital-based educational activities are regularly incorporated into the instructional day. For example, 69% of teachers said their students "sometimes or often" use educational technology to learn or practice basic skills, and 45% said the same about solving problems, analyzing data, or performing calculations (Gray, 2010).

These curricula, alternatively referred to as computer-aided instruction (CAI), come in many forms. In general, digital curriculum programs include some combination of computer-based lessons, activities, and assessments. The lessons often allow students to visualize concepts through videos and simulations, and activities may include games that provide students with virtual "hands-on" experiences. Assessments are typically used to check understanding and give students immediate feedback. In addition, the programs often include features for teachers to track individual student performance and identify common misconceptions.

Another feature of these programs is that they are typically designed to support or enhance a teacher's daily instruction, rather than serve as a teacher substitute. Their potential to improve instructional quality and student learning is tied to their ability to help teachers differentiate and personalize the learning process, and help students become active learners. Prior research on digital curriculum, including educational games, indicates that these programs can improve student learning, but not all programs are equally effective (Cheung & Slavin, 2013; Clark, Tanner-Smith, & Killingsworth, 2016). For example, What Works Clearinghouse (WWC) reviews of specific programs found mixed effects for *Cognitive Tutor® Algebra I* (WWC, 2016), "potentially positive" effects for *Odyssey® Math* (WWC, 2017a), and no effects for *I CAN Learn® Algebra* (WWC, 2017b).

As the use of innovative digital curriculum programs expands, so does the need for rigorous evidence about their effects. This symposium brings together studies of three different digital math programs with features intended to enhance instruction. The first paper uses a cluster randomized design to look at the effects of *Reasoning Mind* on fifth grade learning. The second paper uses a cluster randomized design to examine the effects of using *Intensified Algebra* for a double-period Algebra I course. The third paper uses a comparative interrupted time series design to examine the effects of using *TenMarks Math* in grade 3-8 classrooms. Together, the papers raise important questions about evaluating the effects of digital curriculum programs and how practitioners can best use such research.

Dr. John Pane (RAND) has agreed to serve as the discussant.

PAPER 1

Abstract Title
Efficacy of an Integrated Core Digital Curriculum for Elementary School Mathematics

Authors
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Background
As schools and districts seek to improve student mathematics achievement and align curricula with new standards, a wave of new curriculum adoptions has occurred that includes many digital core curricula. Research shows the potential of these new digital curricula, for example, to blend the role of teacher and technology in supporting student learning (Means et al., 2010). The new digital resources also measure students' progress to adapt or differentiate instruction (Corbett et al., 2001). To date, little systematic research exists to explore whether such approaches effectively increase student achievement and how implementation of such programs may alter teaching and learning.

Purpose
This study advances this discourse through a large-scale randomized controlled trial (RCT) of the Reasoning Mind (RM) program. RM provides a fully-developed grade 5 digital math curriculum that combines online and face-to-face instruction in the classroom, along with ongoing implementation support and teacher PD. The program had shown promise in prior studies (Waxman & Houston, 2008, 2012) and was ready for experimental trial at scale. The goals of the research were (a) to evaluate the impact of the RM program on student learning, and (b) to investigate shifts in teaching practices and classroom interactions.

Setting
The study took place in the state of West Virginia (WV). Mathematics achievement in WV has been below the national averages (NCES, 2011), motivating adoption of new programs. Despite being more rural and higher poverty than national averages (Johnson & Strange, 2007; Provasnik et al., 2007), WV had several initiatives that had already established a robust technology infrastructure that would support digital curriculum at scale.

Population
We recruited voluntary participation from elementary and middle schools with grade 5 students throughout WV. The final sample consisted of 46 schools, comprising 1,829 grade 5 students and their teachers.

Intervention
RM was offered to schools as an integrated service, comprising technology, a full year curriculum, and teacher support. In an RM classroom, students work individually on computers, moving at their own pace through the curriculum. The system is adaptive, differentiating instruction for students and providing reports for teachers about individual student progress and performance. Teachers monitor student data and pull individuals or small groups for

interventions accordingly. Each school is supported by an implementation coordinator (IC) who coaches teachers in achieving high-quality implementations.

Research Design

The study was a 2-year RCT, with random assignment at the school level. Treatment teachers used RM as their core curriculum, and control teachers used their business-as-usual curricula. We considered the first year a "warm up" year for RM teachers. We report here on findings from the second year. The main outcome measure was the West Virginia General Summative Assessment (WVGSA) for grade 5 mathematics. We also used the grade 4 WVGSA to test for baseline equivalence of groups and to control for prior achievement. We also gathered complementary data about program implementation and school context.

Data Collection

We obtained students' grade 5 and grade 4 WVGSA scores from the WV Department of Education. We collected school-level demographic information from public databases. Complementary sources of data included a teacher survey each spring, a series of lesson logs throughout the school year, interviews with teachers and administrators, classroom observations, interviews with ICs, focus groups with RM students, and RM system data.

Data Analysis

First we established baseline equivalence between the two conditions on students' prior year achievement. Next we analyzed the experimental treatment effect using a 2-level (student nested within school) hierarchical linear model (HLM) with grade 4 prior achievement as a covariate. We conducted systematic qualitative analysis of Interviews and observations and descriptive analyses of quantitative data, incorporating variables into our HLM model to examine potential relationships with achievement.

Findings

We found that the experimental treatment effect was not statistically significant; the WVGSA in the treatment and control schools was statistically indistinguishable ($p = 0.34$, $z=-0.96$). We also tested the treatment effect independently for each WVGSA proficiency level, and none was significant.

Complementary analyses compared teaching and learning among the two groups. Key differences include:

- Treatment teachers had much greater access to real-time data on student learning that they could use to support learning.
- Treatment teachers used most of their time for one-on-one interventions, while control teachers spent more time delivering full class instruction.
- Treatment teachers viewed their role as more of a coach. For some, this was a positive experience of being better able to provide one-on-one support, while others felt uncomfortable, unsure how to manage the classroom, or relegated to being a lab monitor.
- Treatment students were able to work through the curriculum at their own pace. This self-pacing had some negative impacts, as some students did not make it through the grade-

level learning objectives. This could directly impact performance on the assessment and indicates a tension between mastery and coverage that needs further investigation.

- Independent learning strategies were more evident among treatment students. At grade 5, it is possible that many students may not have had the readiness to self-regulate their learning to the extent necessary to be successful.
- Peer interactions were more prevalent in control classrooms. In focus groups, many treatment students reported that they missed having more opportunities to interact with their classmates.

Conclusion

This efficacy study was motivated by the need for rigorous research to explore whether digital learning approaches effectively increase student achievement and how implementation of such programs may alter teaching and learning. Overall, we did not detect significant differences in achievement for students using the RM digital curriculum and those using a business-as-usual curriculum. There are many reasons why this may be the case. In our presentation, we will explore the potential roles of measurement, implementation quality, underlying theory, and contextual factors. We did, however, observe many shifts in teaching and learning--some that provided significant advantages and some that brought new challenges for teachers and students. We will examine these shifts, how they may have supported or hindered learning, and critical lessons for practitioners and researchers seeking new and innovative approaches to improving student achievement.

PAPER 2

Abstract Title
Extra Support for At-Risk Ninth Graders: An Efficacy Study of a Double Dose Algebra I Digital Curriculum

Authors
Kirk Walters, Rachel Garrett, Dioni Garcia-Piriz, Rui Yang, Jen Ford, and Melissa Yisak
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Background
Algebra I is a persistent stumbling block for our nation's at-risk students (Ham & Walker, 1999; Helfand, 2006), and students who fail Algebra I have a lower likelihood of graduating high school on time (Heppen et al., 2013; Legters & Kerr, 2001; Oriheula, 2006; Silver, Saunders, & Zarate, 2008). A common response is to provide at-risk students an extra period of algebra ("double dose"), but research shows mixed results and challenges to implementing in a way that makes productive use of the expanded time (Balfanz, Byrnes & Legters, 2006).

Among double-dose algebra programs, Intensified Algebra (IA) has been gaining attention and increased use. IA is a year-long, technology-enhanced program that targets the academic needs and learning mindset of at-risk students—students one to three years behind grade level in mathematics. The blended program consists of a complete digital curriculum that teachers use to lead students in daily instruction. Figure A1 shows the theory of action. The program is designed to increase students' math engagement and produce more positive perceptions of themselves as math learners, leading to greater learning and passing rates in Algebra I and beyond. Early, small scale investigations have suggested positive results for IA both in student outcomes and teacher experiences with implementation, but more rigorous research is needed.

Purpose
This study is the first randomized controlled trial of the IA program. The results of the study will inform the field of the potential benefits and challenges of implementing a digital curriculum for a double-dose Algebra I program.

Impact Questions

1. What is the impact of IA on at-risk 9th graders' short-term academic outcomes?
2. What is the impact of IA on at-risk 9th graders' engagement, motivation, and confidence in mathematics?
3. Does the impact of IA differ for students with different background characteristics?

Implementation Questions

4. To what degree are the core components of IA enacted with fidelity?
5. Which implementation factors are related to student outcomes?

Research Design
The study used a cluster randomized design: within a district, 50% of participating schools were assigned to implement the IA program (treatment), and the other 50% were assigned to continue with their business-as-usual double-dose algebra courses (control). Schools used their usual

methods for determining which students constituted the target population for the program, meaning the schools identified which of their rising 9th graders they considered one to three grade levels behind. This way the student sample reflected a real-world situation (as opposed to using a criterion imposed by the study team).

Sample

The study took place in 48 public high schools in 12 districts across two cohorts. Twenty-three schools participated in 2015–16 (Cohort 1) and 25 schools participated during the 2016-17 school year (Cohort 2). Across both cohorts, 109 teachers and over 5,000 students were involved in the study.

High schools in participating districts were eligible for the study if they (1) offered at least one section of extended time Algebra I taught by the same teacher, and (2) were not already implementing the IA program. In addition, a participating double dose Algebra section must have targeted 9th graders who had never taken Algebra I and were 1-3 years below grade level in math.

Prior to randomization, schools submitted a list of study-eligible students. Students identified from these lists were considered the study cohort, whether or not they remained in the study section throughout the year. Teachers of eligible, double dose Algebra sections were invited to participate in the study.

Measures and Methods

Short term student outcomes. To measure short-term learning in algebra, we administered the nationally-normed Acuity Algebra Proficiency assessment to all 9th graders in the double-dose Algebra I courses in treatment and control schools in the spring of each cohort year. We also collected transcript information to assess Algebra I passing rates. To measure students' learning mindset, we administered a student survey at the end of the intervention year, using validated measures to capture learning behaviors and attitudes such as engagement, persistence, and growth mindset.

Performance in subsequent math courses. We are collecting transcript data to track the types of courses taken and grades received by students in study schools over time. For the main analyses of the impact of IA on subsequent coursetaking, we will create binary indicators of whether (or not) students successfully pass the course that is on grade level for their year in high school.

Implementation measures. Working in close collaboration with the program developers, we have developed an "implementation index" comprised of 27 indicators to demonstrate the degree to which teachers implemented the program with fidelity (low, mid or high indicators). The indicators are based on the usage data collected through the digital curriculum, in addition to short surveys treatment teachers completed at the end of each instructional unit.

Approach. Our primary analytic method for addressing the three questions about program impacts will be hierarchical linear modeling, which explicitly takes into account the clustering of students within classrooms and classrooms within schools. The main impact analyses will be intent-to-treat analyses, which assess the impacts of being randomly assigned to the treatment condition as opposed to the impacts of treatment received. Secondary analysis will also consider the treatment-on-the-treated estimates. We will use the Acuity and student survey measures as our primary outcomes of interest, and will test for moderating effects by subgroups of students. We will also explore how level of implementation fidelity is associated with student outcomes through inclusion of the implementation index.

Findings and Conclusion

Analyses are ongoing and will be ready for presentation in early winter. Our early indications suggest that teachers in the first cohort did not implement the program with the intended fidelity, for example not spending the expected amount of time in daily use of the online lessons (see Exhibit A2 in the appendix.) Forthcoming results, which will be completed prior to the SREE 2018 conference, will pool across both cohorts to indicate the impacts on student academic and attitudinal outcomes, and will describe implementation fidelity and its relationship to student outcomes.

PAPER 2 APPENDIX

Exhibit A1: Intensified Algebra Theory of Action

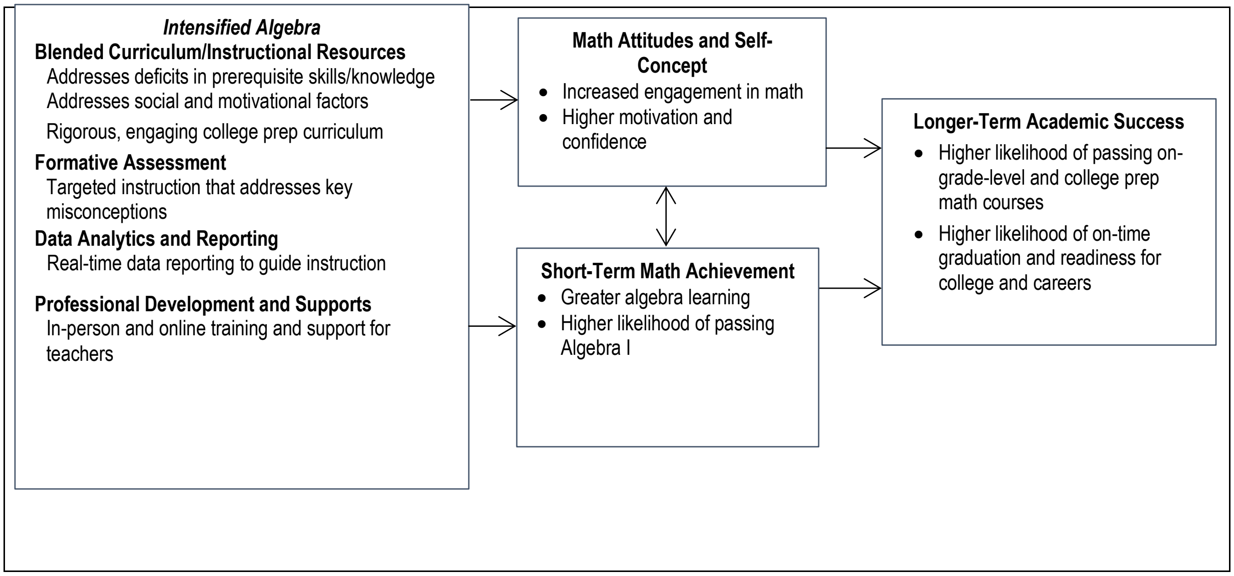
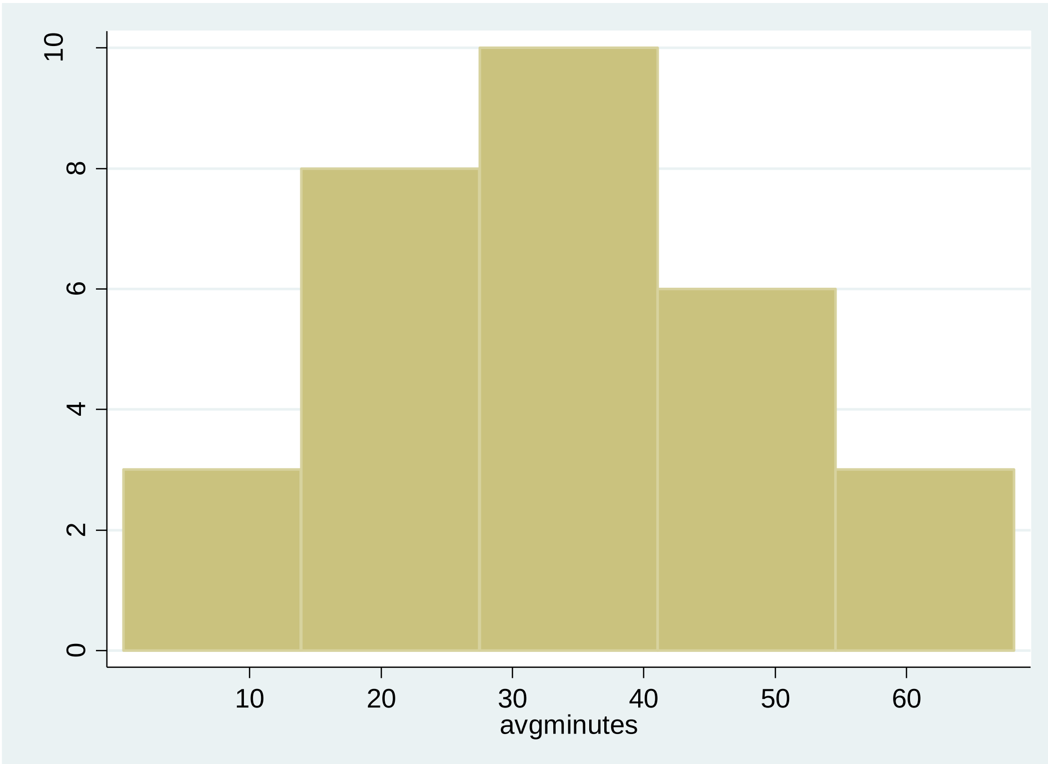


Exhibit A2. Fidelity of Implementation among Cohort One Teachers: Average Daily Time Spent Using Online Lessons



Daily Time on IA Lessons: Cohort One	**N of Teachers**	**Percent**
Low: Less than 30 daily minutes	12	40
Mid: 30-45 daily minutes	11	37
High: More than 45 daily minutes	7	23

PAPER 3

Abstract Title
The Effect of TenMarks Math on Student Achievement

Authors
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(American Institutes for Research)

Purpose
Teachers face rapidly expanding options and opportunities to incorporate digital content and resources in their classrooms. But the research field is struggling to keep up with the demand for quality information on the effectiveness of specific programs, particularly studies that examine how effective programs are when implemented in real-world classroom conditions.

This paper provides evidence on the effectiveness of a popular web-based mathematics curriculum, TenMarks Math, as it was naturally implemented across a variety of schools across ten states. In particular, we address the following research questions:

1. To what extent does access to the TenMarks Math program affect student mathematics achievement in the first year?
2. To what extent does systematic usage of the TenMarks Math program affect student mathematics achievement?
3. To what extent does the effect of TenMarks Math different across school settings?
    a. What is the average effect in the first year in schools in which most students are low income?
    b. What is the average effect in the first year in schools in which most students are an underrepresented minority?

Program
TenMarks Math provides teachers with digital content, including lessons, assignments, and assessments that are aligned to Common Core standards. The program is designed to help teachers differentiate instruction and personalize learning. For example, teachers can differentiate assignments based on recommendations generated by the program and use data dashboards and reports to inform student needs. Students receive immediate feedback on assignments, and the program provides “just-in-time” interventions based on individual student performance. To help students master concepts, the program presents content in multiple levels of abstraction and in multiple formats (e.g., diagrams, pictures, and animations). The developer recommends that, at a minimum, students use TenMarks Math frequently enough to attempt one assignment per week.

Population and Setting
The analysis is based on 584 schools, across 153 school districts, in ten states: California, Florida, Illinois, Louisiana, Massachusetts, North Carolina, New Jersey, Ohio, Virginia, and Washington. Within these states, we identified grade 3–8 classes (defined as grades within schools) that had grade-level access to TenMarks Math in the 2013–14, 2014–15, or 2015–16

school year. Grade-level access was defined as grades in which there were TenMarks Math student licenses for at least 75% of the students enrolled in the grade in.

We did not have access to individual student or classroom data within a school; therefore, our unit of analysis is the grade-level class, in aggregate, within schools for a particular year. To be included in the analysis, classes had to meet the following criteria:

- Have student enrollment reported in the Common Core of Data (CCD) for that cohort year.
- Have state mathematics assessment results in the state's publicly available reporting system for 3 years prior to the cohort year through the 2015–16 school year.

Overall, 1,316 of the 1,408 classes that had access to TenMarks Math met the analysis inclusion criteria. See Table A.1 for the number of districts, schools, and classes that met the inclusion criteria in each state.

Of the classes that met the inclusion criteria, 25% were Grade 3, 27% were Grade 4, 26% were Grade 5, 11% were Grade 6, 7% were Grade 7, and 5% were Grade 8. Among the TenMarks schools, 56% received schoolwide Title I funding, 20% of the students were Black, and 24% were Hispanic.

Research Design

We used a comparative interrupted time series design to estimate the effect of TenMarks Math on student mathematics achievement. To identify comparable classes, we matched each TenMarks Math class with a class in the same grade, state, and location (urban, suburban, or town/rural) that had no exposure to TenMarks Math. Matches were identified with a combination of exact and nearest-neighbor propensity score matching. The characteristics used for matching and the matching results are presented in Table A.2.

To estimate the effects of TenMarks Math, we used a baseline mean model with three years of pre-treatment data and one year of post-treatment data. The model included covariates for each class's grade, cohort, and school characteristics, and we used estimation procedures that adjusted the standard errors for the autoregressive nature of the annual outcome measures and the clustering of classes within schools. We estimated separate models for each state and combined results across states with a fixed-effects meta-analysis of the state-specific effect estimates.

Data Collection

We used three data sources for the study: school enrollment and characteristics from the CCD, aggregate public-use data from end-of-year mathematics assessments in each state, and TenMarks Math program usage data reported for each grade within schools that used TenMarks Math. Only 6 of the 10 states had public-use assessment data that included average mathematics scale scores for the study time period, but the assessment data for all 10 states included the percentage of students who scored at or above the state's proficiency benchmark. Therefore, we used the mathematics percent proficient for each class as our measure of mathematics achievement. To properly examine differences in percent proficient across classes and time, we converted each percent proficient score to a log-odds score and then standardized the log-odds score based on the mean and standard deviation within each grade, state, and year.

Findings
We have the following key findings:

- TenMarks Math improved average mathematics performance by 0.11 standard deviations in the first year of access, relative to classes that did not have the program (see Figure A.1).

- 35% of the classes with access to TenMarks Math systematically used the program (defined as classes that averaged at least one assignment per week during the year). In classes that systematically used TenMarks Math during the first year, TenMarks Math improved average mathematics performance by 0.19 standard deviations, relative to classes that did not have the program (see Figure A.2).

- The estimated effect of having access to TenMarks Math during the first year was relatively similar across school settings, specifically low-income schools (0.11 standard deviations; see Figure A.3) and high-minority schools (0.14 standard deviations; see Figure A.4).

Conclusions
The results suggest that digital content programs like TenMarks Math can effectively improve student achievement when implemented under standard classroom conditions. The full paper will provide a more detailed examination of effect heterogeneity, particularly as it relates to program usage and school context.

PAPER 3 APPENDIX

Table A.1. Number of Districts, Schools, and Classes That Met the Analysis Inclusion Criteria

State	Districts	Schools	Classes
CA	37	128	247
FL	11	72	179
IL	17	50	103
LA	5	49	121
MA	17	43	89
NC	19	36	72
NJ	14	25	58
OH	21	79	201
VA	8	84	201
WA	4	18	45
Total	**153**	**584**	**1,316**

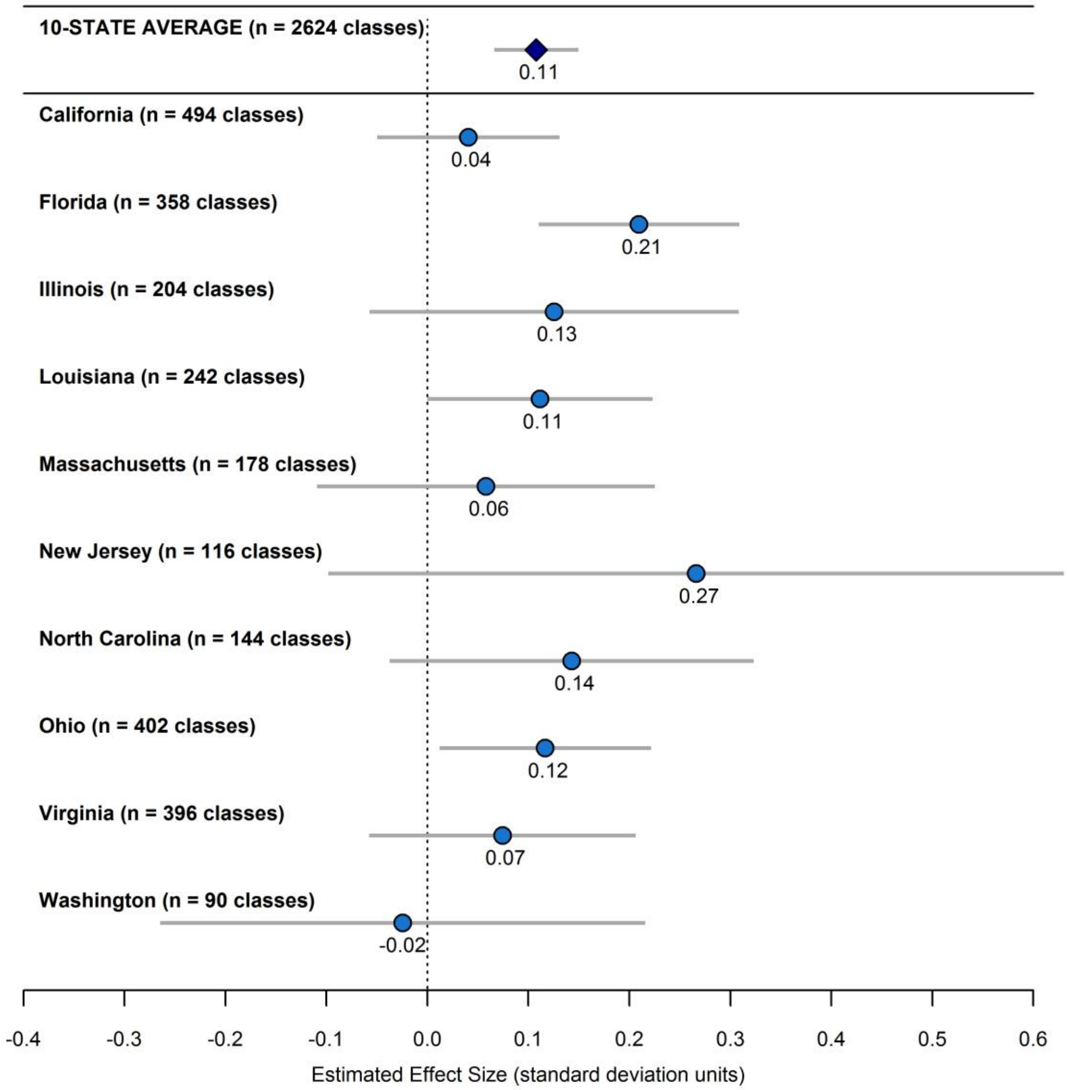
Exhibit A.2. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts and States

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (*N* = 1,312)	C Mean (*N* = 1,312)	SMD	C Mean (*N* = 39,357)	SMD
Location: City	0.32	0.32	0.00	0.32	0.01
Location: Suburb	0.54	0.54	0.00	0.41	0.27
Location: Town/Rural	0.13	0.13	0.00	0.27	-0.31
Magnet School	0.04	0.04	0.00	0.04	-0.04
Charter School	0.03	0.03	0.00	0.07	-0.14
Title I: Targeted	0.13	0.13	0.00	0.17	-0.12
Title I: Schoolwide	0.56	0.59	-0.05	0.61	-0.11
Total enrollment (Grades 3–8)	356.85	345.45	0.05	332.06	0.11
Percent NSLP	0.52	0.52	0.01	0.57	-0.17
Percent Black	0.20	0.19	0.03	0.15	0.21
Percent Asian/Pacific Islander	0.07	0.06	0.01	0.06	0.04
Percent Hispanic	0.24	0.24	0.02	0.31	-0.21
Percent White	0.44	0.46	-0.05	0.43	0.03
Percent Proficient: Prior Year 3	0.70	0.69	0.03	0.63	0.36
Percent Proficient: Prior Year 2	0.69	0.69	0.04	0.63	0.30
Percent Proficient: Prior Year 1	0.63	0.63	0.00	0.43	0.79

Notes. The table includes statistics for all eligible comparison classes in Cohort 3, rather than all cohorts, because most eligible classes are in the eligible pool for multiple cohorts. The statistics for all eligible comparison classes in Cohort 3 provide a general reference for how the TenMarks Math classes compare to the broader population of eligible classes and how matching improved comparability. The means for the four race/ethnicity composition measures do not sum to 1 because the Native American and “multiple race” categories are not reported in the table.

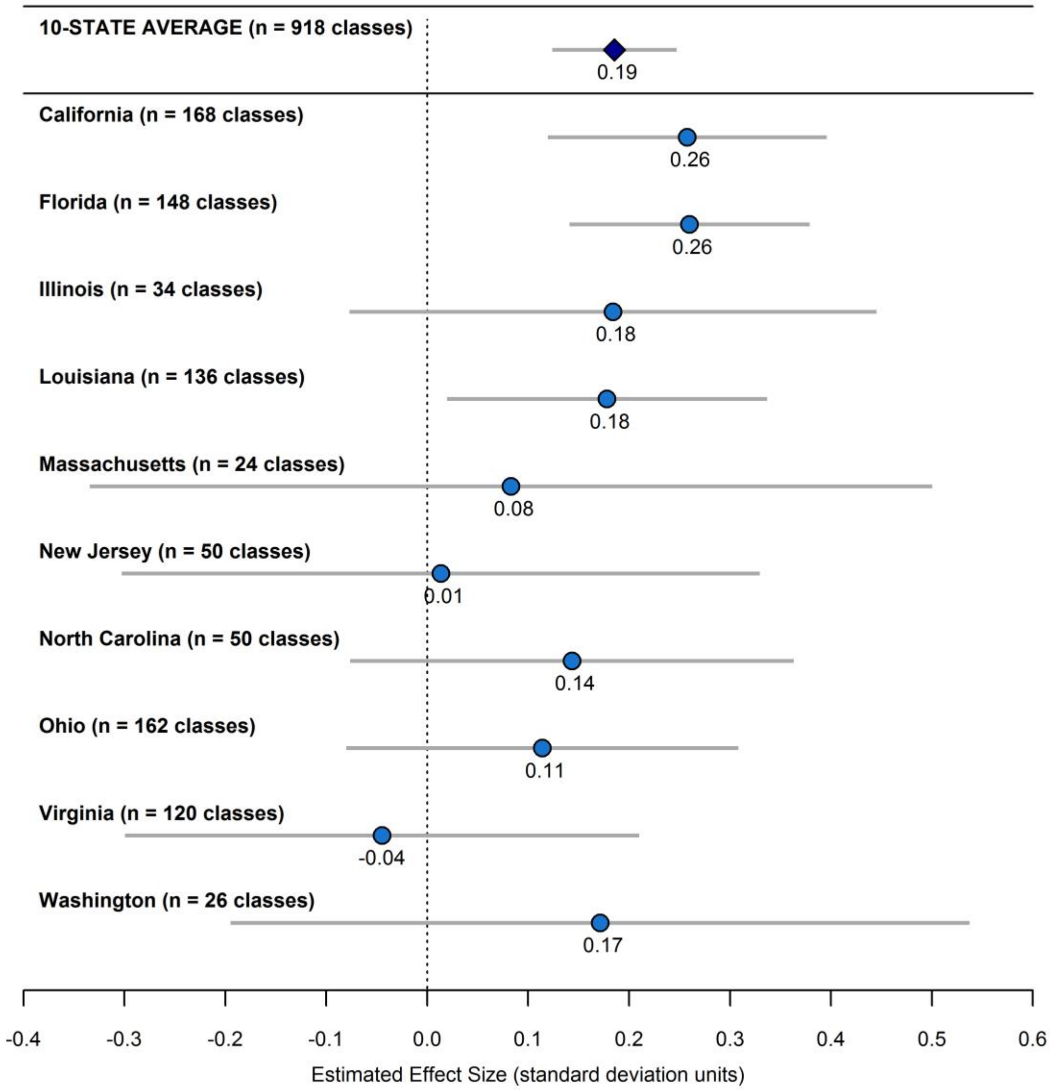
TM = TenMarks Math class; C = comparison class; SMD = standardized mean difference.

Figure A.1. Estimated Effect of Access to TenMarks Math on Mathematics Achievement in the First Year of Implementation



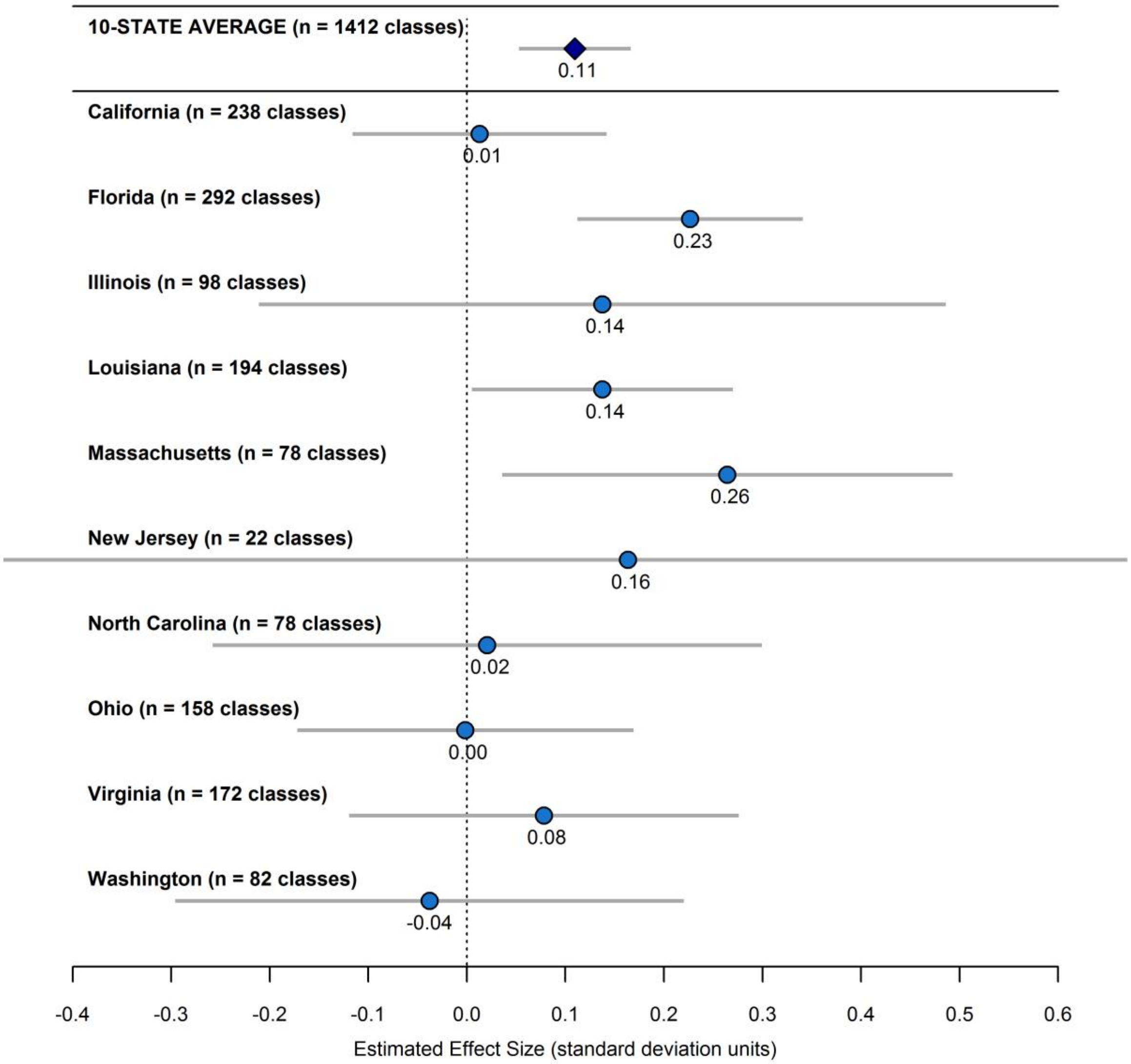
Notes. The exhibit presents the estimated effect of having access to TenMarks Math, where the effect is measured in standard deviations of the class-level percent proficient (log-odds) on the state's mathematics assessment. The horizontal gray line represents the 95% confidence interval for the estimated effect. Reported sample sizes indicate the number of TenMarks Math classes plus the number of matched comparison classes included in the analysis.

Figure A.2. Estimated Effect of TenMarks Math Systematic Usage on Mathematics Achievement in the First Year of Implementation



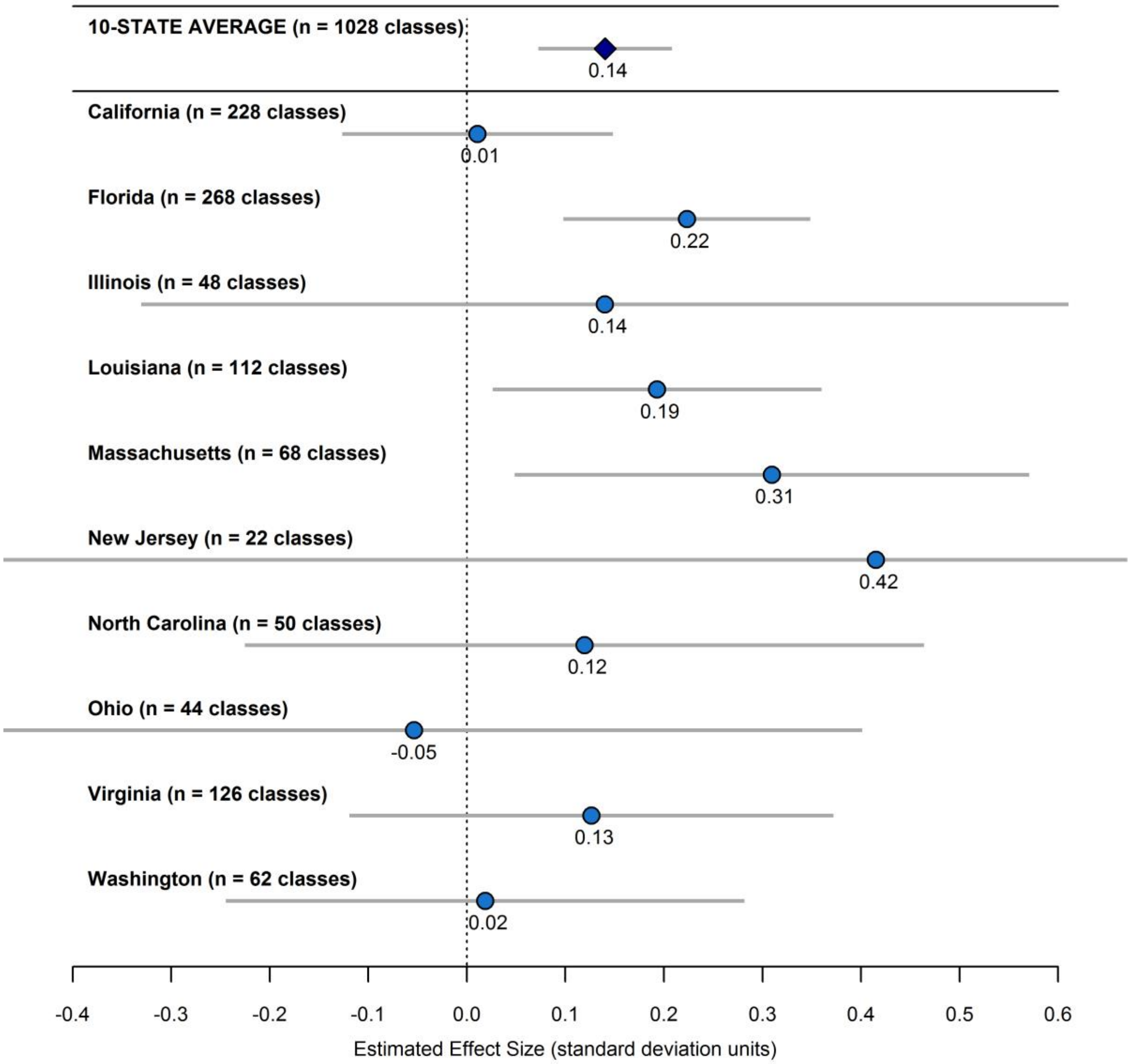
Notes. The exhibit presents the estimated effect of systematically using TenMarks Math, where the effect is measured in standard deviations of the class-level percent proficient (log-odds) on the state's mathematics assessment. The horizontal gray line represents the 95% confidence interval for the estimated effect. Reported sample sizes indicate the number of TenMarks Math classes plus the number of matched comparison classes included in the analysis.

Table A.3. Estimated Effect of Access to TenMarks Math on Mathematics Achievement in the First Year of Implementation in Low-Income Schools



Notes. The exhibit presents the estimated effect of having access to TenMarks Math, where the effect is measured in standard deviations of the class-level percent proficient (log-odds) on the state's mathematics assessment. The horizontal gray line represents the 95% confidence interval for the estimated effect. Reported sample sizes indicate the number of TenMarks Math classes plus the number of matched comparison classes included in the analysis.

Table A.4. Estimated Effect of Access to TenMarks Math on Mathematics Achievement in the First Year of Implementation in High-Minority Schools



Notes. The exhibit presents the estimated effect of having access to TenMarks Math, where the effect is measured in standard deviations of the class-level percent proficient (log-odds) on the state's mathematics assessment. The horizontal gray line represents the 95% confidence interval for the estimated effect. Reported sample sizes indicate the number of TenMarks Math classes plus the number of matched comparison classes included in the analysis.

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