



The Effect of TenMarks Math on Student Achievement: Technical Supplement

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AUGUST 2017

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2029_07/17

Contents

	Page
Introduction.....	1
Calculation of the Percent Proficient Outcome Metric.....	1
Number of Matched TenMarks Math Classes Included in Each Analysis	2
Detailed Matching Results.....	2
Impact Model Details.....	12
RQ 1: The Effect of TenMarks Math Access in the First Year	12
RQ 2: The Effect of TenMarks Math Access Over 2 Years	13
RQ 3 and RQ 4: The Effect of TenMarks Math Systematic Usage and Access in Different School Settings in the First Year.....	14
Robustness Check: A Broader Definition of Access	15
References.....	17

Exhibits

	Page
Exhibit 1. Number of Matched TenMarks Math Classes Included in Each Analysis, by State.....	2
Exhibit 2. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: California	3
Exhibit 3. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Florida.....	4
Exhibit 4. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Illinois	5
Exhibit 5. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Louisiana.....	6
Exhibit 6. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Massachusetts	7
Exhibit 7. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: North Carolina	8
Exhibit 8. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: New Jersey.....	9

Exhibit 9. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Ohio.....	10
Exhibit 10. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Virginia	11
Exhibit 11. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Washington	12
Exhibit 12. Comparison of Estimated Effects Based on the 75% and 50% Definitions of TenMarks Math Access	16

Introduction

This document is a supplement to the final report for the TenMarks Math Impact Study: *The Effect of TenMarks Math on Student Achievement*. The technical supplement provides additional information about the methods used to estimate the effects of the TenMarks Math program.

Calculation of the Percent Proficient Outcome Metric

For the outcome measure, we calculated a standardized version of each class's mathematics percent proficient score. The standardization included two steps. First, we transformed the percent proficient into a log-odds ratio (or logit) so that the measure would have properties of a normally distributed variable that are assumed for the standardization and linear models used for effect estimation:

$$(1) \textit{logit}_{ijgs} = \log\left(\frac{pp_{ijgs}}{1-pp_{ijgs}}\right),$$

where pp_{ijgs} is the proportion of students for year i in class j within grade g in state s who scored at or above the state's proficiency benchmark on the state's mathematics assessment.

Second, we converted each class's logit score to a z -score metric based on the mean and standard deviation of logit scores within a year, grade and state:

$$(2) \textit{zscore}_{ijgs} = \frac{\textit{logit}_{ijgs} - \overline{\textit{logit}_{igs}}}{SD(\textit{logit})_{igs}},$$

where $\overline{\textit{logit}_{igs}}$ is the mean logit score across all classes within a particular year, grade, and state; and $SD(\textit{logit})_{igs}$ is the standard deviation of the logit scores across all classes within a particular year, grade, and state.

Number of Matched TenMarks Math Classes Included in Each Analysis

Analyses for the study were based on matched pairs of classes, where each TenMarks Math class was matched to a comparison class (one-to-one matching without replacement). Exhibit 1 reports the number of TenMarks Math classes that were included in each analysis, by state. Given one-to-one matching, the total number of classes included in each analysis is twice the number of TenMarks Math classes reported in Exhibit 1.

Exhibit 1. Number of Matched TenMarks Math Classes Included in Each Analysis, by State

State	RQ1: All Classes	RQ2: Classes With 2 Years of Access	RQ3: Systematic Users	RQ4a: Class in Low- Income Schools	RQ4b: Classes in High-Minority Schools
CA	247	75	84	119	114
FL	179	11	74	146	134
IL	102	9	17	49	24
LA	121	80	68	97	56
MA	89	18	12	39	34
NC	72	6	25	39	25
NJ	58	17	25	11	11
OH	201	100	81	79	22
VA	198	9	60	86	63
WA	45	0	13	41	31
Total	1,312	325	459	706	514

Detailed Matching Results

Matching within the comparative interrupted time series (CITS) design can help mitigate potential bias by comparing the outcome trajectories for treatment classes with a matched sample of comparison classes that experience similar external policy and contextual factors (e.g., a state changing the student assessment system or a regional economic downturn). Recent methodological studies demonstrate that CITS designs can produce treatment effect estimates equivalent to randomized controlled trials and regression discontinuity designs (e.g., Hallberg, Williams, & Swanlund, 2015; Jacob, Somers, Zhu, & Bloom, 2016).

Classes with similar propensity scores should have, on average, similar prior achievement and characteristics. To test whether matching on the propensity score improved comparability of the TenMarks Math group and the matched comparison group, we compared the observed characteristics of the two groups. A general rule of thumb for determining whether the two groups are similar is if the standardized mean difference (SMD) on measurable characteristics is less than 0.25 standard deviations (What Works Clearinghouse, 2014). The matching results pooled across the 10-state sample were presented in the main report. In this supplement, we provide the matching results for each state in Exhibits 2 through 11.

Exhibit 2. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: California

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 247)	C Mean (N = 247)	SMD	C Mean (N = 13,850)	SMD
Location: City	0.23	0.23	0.00	0.44	-0.43
Location: Suburb	0.72	0.72	0.00	0.40	0.65
Location: Town/Rural	0.06	0.06	0.00	0.16	-0.29
Magnet School	0.03	0.03	0.00	0.05	-0.10
Charter School	0.02	0.02	0.00	0.10	-0.26
Title I: Targeted	0.17	0.18	-0.05	0.12	0.13
Title I: Schoolwide	0.48	0.48	0.00	0.66	-0.38
Total enrollment (grades 3–8)	423.72	400.37	0.11	352.34	0.32
Percent NSLP	0.47	0.45	0.07	0.64	-0.61
Percent Black	0.03	0.03	0.00	0.06	-0.30
Percent Asian/Pacific Islander	0.14	0.16	-0.16	0.10	0.28
Percent Hispanic	0.46	0.46	0.03	0.55	-0.29
Percent White	0.32	0.30	0.09	0.24	0.32
Percent Proficient: Prior Year 3	0.72	0.73	-0.05	0.63	0.52
Percent Proficient: Prior Year 2	0.72	0.73	-0.06	0.62	0.53
Percent Proficient: Prior Year 1	0.56	0.57	-0.03	0.32	1.22

Note. 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.

Exhibit 3. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Florida

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 179)	C Mean (N = 179)	SMD	C Mean (N = 3,787)	SMD
Location: City	0.29	0.29	0.00	0.29	0.00
Location: Suburb	0.59	0.59	0.00	0.54	0.11
Location: Town/Rural	0.12	0.12	0.00	0.17	-0.14
Magnet School	0.15	0.15	0.00	0.12	0.09
Charter School	0.13	0.13	0.00	0.17	-0.10
Title I: Targeted	0.01	0.01	-0.03	0.04	-0.19
Title I: Schoolwide	0.80	0.80	0.01	0.82	-0.05
Total enrollment (grades 3–8)	389.07	358.22	0.10	436.56	-0.15
Percent NSLP	0.70	0.68	0.07	0.62	0.29
Percent Black	0.35	0.31	0.15	0.24	0.45
Percent Asian/Pacific Islander	0.03	0.02	0.10	0.02	0.06
Percent Hispanic	0.32	0.34	-0.08	0.32	0.01
Percent White	0.27	0.29	-0.07	0.38	-0.40
Percent Proficient: Prior Year 3	0.58	0.59	-0.09	0.53	0.23
Percent Proficient: Prior Year 2	0.58	0.58	0.02	0.55	0.19
Percent Proficient: Prior Year 1	0.55	0.56	-0.04	0.52	0.18

Note. 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 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.

Exhibit 4. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Illinois

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 102)	C Mean (N = 102)	SMD	C Mean (N = 5,543)	SMD
Location: City	0.17	0.17	0.00	0.36	-0.40
Location: Suburb	0.66	0.66	0.00	0.33	0.69
Location: Town/Rural	0.18	0.18	0.00	0.31	-0.29
Magnet School	0.02	0.02	0.00	0.03	-0.08
Charter School	0.00	0.00	0.00	0.02	-0.13
Title I: Targeted	0.26	0.19	0.17	0.30	-0.08
Title I: Schoolwide	0.45	0.51	-0.12	0.55	-0.20
Total enrollment (grades 3–8)	280.09	313.21	-0.17	290.89	-0.06
Percent NSLP	0.45	0.49	-0.15	0.60	-0.54
Percent Black	0.10	0.11	-0.04	0.23	-0.39
Percent Asian/Pacific Islander	0.06	0.05	0.10	0.03	0.33
Percent Hispanic	0.26	0.31	-0.18	0.20	0.21
Percent White	0.54	0.50	0.11	0.50	0.10
Percent Proficient: Prior Year 3	0.73	0.70	0.15	0.56	0.82
Percent Proficient: Prior Year 2	0.69	0.65	0.20	0.58	0.54
Percent Proficient: Prior Year 1	0.46	0.43	0.18	0.26	1.04

Note. 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 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.

Exhibit 5. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Louisiana

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 121)	C Mean (N = 121)	SMD	C Mean (N = 1,743)	SMD
Location: City	0.34	0.34	0.00	0.18	0.43
Location: Suburb	0.29	0.29	0.00	0.20	0.22
Location: Town/Rural	0.37	0.37	0.00	0.62	-0.52
Magnet School	0.04	0.04	0.00	0.06	-0.10
Charter School	0.00	0.00	0.00	0.04	-0.22
Title I: Targeted	0.00	0.00	0.00	0.01	-0.11
Title I: Schoolwide	0.97	0.95	0.06	0.91	0.21
Total enrollment (grades 3–8)	352.62	332.84	0.11	280.25	0.39
Percent NSLP	0.70	0.71	-0.05	0.67	0.12
Percent Black	0.44	0.47	-0.08	0.40	0.14
Percent Asian/Pacific Islander	0.01	0.01	0.03	0.01	0.07
Percent Hispanic	0.06	0.06	-0.04	0.05	0.09
Percent White	0.47	0.42	0.14	0.51	-0.13
Percent Proficient: Prior Year 3	0.72	0.67	0.28	0.70	0.13
Percent Proficient: Prior Year 2	0.71	0.66	0.28	0.72	-0.03
Percent Proficient: Prior Year 1	0.71	0.68	0.18	0.62	0.47

Note. 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 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.

Exhibit 6. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Massachusetts

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 89)	C Mean (N = 89)	SMD	C Mean (N = 1,962)	SMD
Location: City	0.09	0.09	0.00	0.22	-0.31
Location: Suburb	0.85	0.85	0.00	0.61	0.50
Location: Town/Rural	0.06	0.06	0.00	0.17	-0.31
Magnet School	0.00	0.00	0.00	0.00	0.00
Charter School	0.02	0.02	0.00	0.07	-0.19
Title I: Targeted	0.10	0.12	-0.05	0.29	-0.42
Title I: Schoolwide	0.42	0.44	-0.05	0.36	0.12
Total enrollment (grades 3–8)	414.47	431.24	-0.08	300.60	0.52
Percent NSLP	0.45	0.43	0.10	0.42	0.11
Percent Black	0.05	0.05	-0.01	0.09	-0.30
Percent Asian/Pacific Islander	0.06	0.06	0.03	0.06	0.03
Percent Hispanic	0.34	0.27	0.31	0.18	0.76
Percent White	0.52	0.59	-0.22	0.63	-0.37
Percent Proficient: Prior Year 3	0.58	0.57	0.06	0.58	0.01
Percent Proficient: Prior Year 2	0.57	0.55	0.08	0.58	-0.05
Percent Proficient: Prior Year 1	0.57	0.57	0.01	0.54	0.14

Note. 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.

Exhibit 7. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: North Carolina

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 72)	C Mean (N = 72)	SMD	C Mean (N = 1,798)	SMD
Location: City	0.22	0.22	0.00	0.24	-0.05
Location: Suburb	0.31	0.31	0.00	0.17	0.38
Location: Town/Rural	0.47	0.47	0.00	0.59	-0.24
Magnet School	0.08	0.08	0.00	0.05	0.15
Charter School	0.06	0.06	0.00	0.11	-0.18
Title I: Targeted	0.06	0.06	0.00	0.05	0.04
Title I: Schoolwide	0.74	0.76	-0.07	0.83	-0.25
Total enrollment (grades 3–8)	380.01	373.14	0.03	305.38	0.33
Percent NSLP	0.53	0.54	-0.02	0.64	-0.41
Percent Black	0.24	0.20	0.15	0.24	-0.03
Percent Asian/Pacific Islander	0.03	0.03	-0.09	0.02	0.09
Percent Hispanic	0.16	0.16	-0.04	0.15	0.07
Percent White	0.53	0.57	-0.13	0.53	0.00
Percent Proficient: Prior Year 3	0.59	0.62	-0.16	0.44	0.83
Percent Proficient: Prior Year 2	0.56	0.56	0.01	0.53	0.18
Percent Proficient: Prior Year 1	0.56	0.58	-0.12	0.52	0.18

Note. 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.

Exhibit 8. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: New Jersey

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 58)	C Mean (N = 58)	SMD	C Mean (N = 2,994)	SMD
Location: City	0.05	0.05	0.00	0.09	-0.13
Location: Suburb	0.86	0.86	0.00	0.78	0.20
Location: Town/Rural	0.09	0.09	0.00	0.13	-0.14
Magnet School	0.00	0.00	0.00	0.00	0.00
Charter School	0.10	0.10	0.00	0.04	0.30
Title I: Targeted	0.48	0.38	0.21	0.51	-0.05
Title I: Schoolwide	0.02	0.03	-0.04	0.22	-0.50
Total enrollment (grades 3–8)	314.74	237.52	0.36	295.96	0.09
Percent NSLP	0.30	0.24	0.20	0.36	-0.19
Percent Black	0.13	0.08	0.25	0.14	-0.07
Percent Asian/Pacific Islander	0.31	0.19	1.06	0.09	1.93
Percent Hispanic	0.16	0.16	0.02	0.25	-0.35
Percent White	0.38	0.56	-0.57	0.50	-0.39
Percent Proficient: Prior Year 3	0.83	0.85	-0.08	0.76	0.40
Percent Proficient: Prior Year 2	0.85	0.86	-0.03	0.75	0.56
Percent Proficient: Prior Year 1	0.70	0.71	-0.02	0.40	1.42

Note. 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.

Exhibit 9. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Ohio

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 201)	C Mean (N = 201)	SMD	C Mean (N = 3,725)	SMD
Location: City	0.04	0.04	0.00	0.25	-0.48
Location: Suburb	0.84	0.84	0.00	0.29	1.19
Location: Town/Rural	0.12	0.12	0.00	0.46	-0.67
Magnet School	0.00	0.00	0.00	0.00	0.00
Charter School	0.00	0.00	0.00	0.00	-0.04
Title I: Targeted	0.28	0.31	-0.08	0.17	0.28
Title I: Schoolwide	0.55	0.48	0.14	0.71	-0.36
Total enrollment (grades 3–8)	330.22	338.91	-0.05	282.09	0.27
Percent NSLP	0.45	0.41	0.12	0.54	-0.25
Percent Black	0.17	0.12	0.19	0.18	-0.02
Percent Asian/Pacific Islander	0.03	0.02	0.07	0.01	0.39
Percent Hispanic	0.07	0.06	0.05	0.05	0.16
Percent White	0.67	0.74	-0.22	0.71	-0.11
Percent Proficient: Prior Year 3	0.83	0.83	-0.02	0.72	0.50
Percent Proficient: Prior Year 2	0.82	0.83	-0.02	0.73	0.46
Percent Proficient: Prior Year 1	0.77	0.79	-0.09	0.60	0.72

Note. 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 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.

Exhibit 10. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Virginia

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 198)	C Mean (N = 198)	SMD	C Mean (N = 2,463)	SMD
Location: City	0.93	0.93	0.00	0.14	2.24
Location: Suburb	0.03	0.03	0.00	0.44	-0.83
Location: Town/Rural	0.04	0.04	0.00	0.42	-0.76
Magnet School	0.00	0.00	0.00	0.06	-0.26
Charter School	0.00	0.00	0.00	0.00	0.00
Title I: Targeted	0.01	0.00	0.02	0.12	-0.35
Title I: Schoolwide	0.34	0.54	-0.40	0.36	-0.03
Total enrollment (grades 3–8)	306.24	296.87	0.04	363.96	-0.23
Percent NSLP	0.48	0.55	-0.30	0.44	0.17
Percent Black	0.33	0.37	-0.23	0.18	0.78
Percent Asian/Pacific Islander	0.05	0.05	-0.03	0.06	-0.20
Percent Hispanic	0.11	0.12	-0.10	0.14	-0.19
Percent White	0.44	0.40	0.15	0.57	-0.49
Percent Proficient: Prior Year 3	0.73	0.71	0.12	0.71	0.09
Percent Proficient: Prior Year 2	0.73	0.72	0.06	0.75	-0.10
Percent Proficient: Prior Year 1	0.79	0.77	0.10	0.80	-0.13

Note. 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.

Exhibit 11. Characteristics of Matched TenMarks Math Classes and Comparison Classes Pooled Across Cohorts: Washington

Characteristic	Matched Classes			All Eligible Comparison Classes	
	TM Mean (N = 45)	C Mean (N = 45)	SMD	C Mean (N = 1,492)	SMD
Location: City	0.84	0.84	0.00	0.41	0.89
Location: Suburb	0.16	0.16	0.00	0.34	-0.40
Location: Town/Rural	0.00	0.00	0.00	0.25	-0.58
Magnet School	0.00	0.00	0.00	0.00	0.00
Charter School	0.00	0.00	0.00	0.00	0.00
Title I: Targeted	0.00	0.00	0.00	0.11	-0.35
Title I: Schoolwide	0.98	1.00	-0.05	0.63	0.73
Total enrollment (grades 3–8)	291.71	268.31	0.11	310.20	-0.09
Percent NSLP	0.75	0.74	0.06	0.48	1.14
Percent Black	0.02	0.03	-0.20	0.06	-0.43
Percent Asian/Pacific Islander	0.01	0.05	-0.41	0.09	-0.77
Percent Hispanic	0.65	0.41	1.37	0.20	2.59
Percent White	0.27	0.43	-0.70	0.56	-1.30
Percent Proficient: Prior Year 3	0.45	0.40	0.26	0.62	-0.98
Percent Proficient: Prior Year 2	0.48	0.48	-0.03	0.61	-0.77
Percent Proficient: Prior Year 1	0.37	0.38	-0.04	0.51	-0.75

Note. 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 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.

Impact Model Details

RQ 1: The Effect of TenMarks Math Access in the First Year

For the first research question (RQ), we estimated a baseline mean model with an effect estimate for the first year of program access (i.e., cohort start year). Within the CITS framework, the baseline mean model is considered robust to fluctuations in student performance and modeling issues that can arise with a limited number of baseline years (Bloom, 2003).¹ To estimate the baseline mean model, we used the following hierarchical linear model, estimated separately for each state:

(3.1) Level 1 (Year):

$$Y_{ij} = \beta_{0j} + \beta_{1j}FY1_{ij} + \beta_{2j}X_{ij} + e_{ij}$$

¹ As a robustness test, we also estimated a linear trend model. The 10-state average effect estimate based on the linear trend model is slightly smaller than the effect estimate based on the baseline mean model (0.09 versus 0.11). For each model, the estimates are statistically significant.

(3.2) Level 2 (Class):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}TM_j + \gamma_{02}GRADE_j + \gamma_{03}COHORT_j + \gamma_{04}Z_k + u_{0k}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}TM_k$$

$$\beta_{2j} = \gamma_{20}$$

(3.3) Combined Model:

$$Y_{ij} = \gamma_{00} + \gamma_{01}TM_j + \gamma_{10}FY1_{ij} + \gamma_{11}(FY1_{ij} \times TM_j) + \gamma_{20j}X_{ij} + \gamma_{02}GRADE_j + \gamma_{03}COHORT_j + \gamma_{04}Z_j + e_{ij} + u_{0j}$$

where i indexes years and j indexes classes.

In this model, Y_{ij} is the mathematics percent proficient (standardized) in year i for class j . $FY1_{ij}$ is a dichotomous indicator for whether the outcome measure was in the first follow-up year (i.e., the cohort start year). TM_j is a dichotomous indicator for whether the class had access to TenMarks Math ($TM_j = 1$) or whether the class was a comparison class ($TM_j = 0$). The model includes controls for a vector of time-varying school characteristics (X_{ij}), a vector of dichotomous indicators for each class's grade-level ($GRADE_j$), a vector of dichotomous indicators for each class's cohort ($COHORT_j$), and a vector of time-constant school characteristics (Z_j). The measures included in the time-varying and time-constant school characteristic vectors are the measures included in the matching approach (see Exhibit A.1 in Appendix A of the final report).

With this model specification, the primary parameter of interest is γ_{11} , which represents the average degree to which the difference between the first follow-up year percent proficient and the mean percent proficient in the baseline period differed for classes that had access to TenMarks Math and the comparison classes, adjusting for any differences in school characteristics. This difference-in-difference estimate is the estimated average effect of TenMarks Math during the first year the program was available to students.

To estimate the model, we used estimation procedures that adjust the standard errors for the autoregressive nature of the annual outcome measures and the additional clustering of classes within schools.

To summarize model estimates across each state, we calculated precision-weighted averages, where precision is defined as the inverse of the variance.

RQ 2: The Effect of TenMarks Math Access Over 2 Years

For the second research question, we restricted the analysis to classes that had access to TenMarks Math for at least 2 years (and their matched comparison classes), and estimated two different baseline mean models that parallel the structure of the model used for the first research question. To estimate the average effect in the first year and the average effect in the second year, we used the following hierarchical linear model, estimated separately for each state:

(4.1) Level 1 (Year):

$$Y_{ij} = \beta_{0j} + \beta_{1j}FY1_{ij} + \beta_{2j}FY2_{ij} + \beta_{3j}X_{ij} + e_{ij}$$

(4.2) Level 2 (Class):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}TM_j + \gamma_{02}GRADE_j + \gamma_{03}COHORT_j + \gamma_{04}Z_k + u_{0k}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}TM_k$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}TM_k$$

$$\beta_{3j} = \gamma_{30}$$

(4.3) Combined Model:

$$Y_{ij} = \gamma_{00} + \gamma_{01}TM_j + \gamma_{10}FY1_{ij} + \gamma_{20}FY2_{ij} + \gamma_{11}(FY1_{ij} \times TM_j) + \gamma_{21}(FY2_{ij} \times TM_j) + \gamma_{30j}X_{ij} + \gamma_{02}GRADE_j + \gamma_{03}COHORT_j + \gamma_{04}Z_j + e_{ij} + u_{0j}$$

where i indexes years and j indexes classes.

The terms in this model are defined the same as in Equation 3. However, in addition to the dichotomous indicator for whether the outcome was in the first follow-up year ($FY1_{ij}$), this model includes an additional indicator for whether the outcome was in the second follow-up year ($FY2_{ij}$). This allows us to estimate the average effect of TenMarks Math during the first year the program was available to students (γ_{11}), as well as the average effect of TenMarks Math during the second year the program was available to students (γ_{21}).

The above model provides separate effect estimates for each year that a class had access to TenMarks Math. To estimate the average across the 2 years, we used a model identical to Equation 3, with one important change. Rather than including $FY1_{ij}$ as an indicator for whether the outcome was in the first follow-up year or not, we included FY_{ij} , which was defined as whether the outcome was in the first or second follow-up year ($FY_{ij} = 1$) or a baseline year ($FY_{ij} = 0$).

With this specification, γ_{11} represents the average degree to which the difference between the mean percent proficient in the first 2 follow-up years and the mean percent proficient in the baseline period differed for classes that had access to TenMarks Math for 2 years and the comparison classes, adjusting for any differences in school characteristics. This difference-in-difference estimate is the estimated average effect of TenMarks Math during the first 2 years the program was available to students.

RQ 3 and RQ 4: The Effect of TenMarks Math Systematic Usage and Access in Different School Settings in the First Year

For the third and fourth research questions, we estimated a baseline mean model identical to Equation 3, but restricted the analysis to different subsamples. For the third research question, we restricted the analysis to classes that averaged at least one TenMarks Math assignment per week (and their matched comparison classes). For the fourth research question, we estimated two separate models: one analysis restricted to classes in schools with more than half of their students eligible for free or reduced-price lunch (and their matched comparison classes), and another

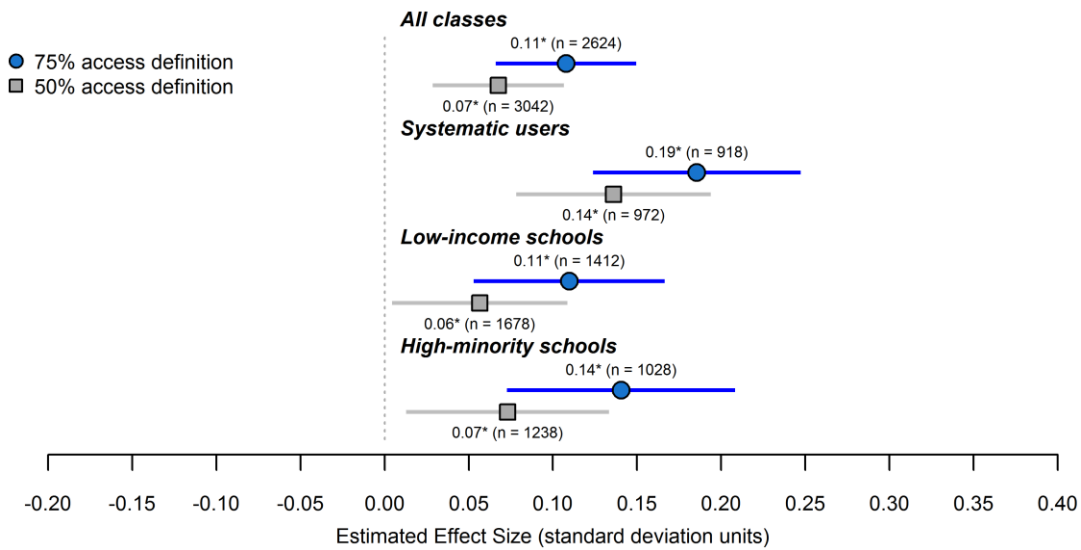
analysis restricted to classes in schools with more than half of their students classified as an underrepresented minority (and their matched comparison classes).

Robustness Check: A Broader Definition of Access

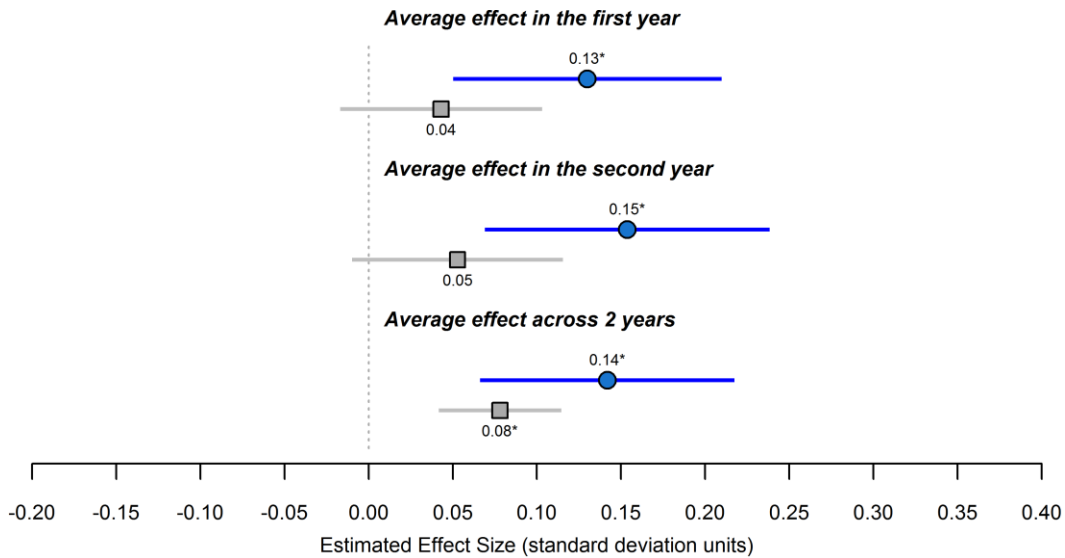
For the analyses of TenMarks Math, we defined TenMarks Math classes as classes that had TenMarks Math student licenses for at least 75% of the students enrolled in the class. To examine how the main results would change if we used a broader definition of access, we conducted a parallel set of analyses that used 50% as the threshold for defining TenMarks Math classes. With this definition, the analyses include 1,521 TenMarks Math classes rather than 1,312. Effect estimates from this broader definition of TenMarks Math classes are presented in Exhibit 12. As expected, the effect estimates are smaller when the analysis is expanded to include classes that had TenMarks Math licenses for only 50% to 74% of their students, but the estimates are still positive and statistically significant for effects in the first year of implementation.

Exhibit 12. Comparison of Estimated Effects Based on the 75% and 50% Definitions of TenMarks Math Access

A. Effects in the first year of implementation



B. Effects over 2 years of implementation in classes with 2 years of access (n = 650 classes for 75% definition and 1,370 classes for 50% definition)



Notes. The exhibit presents the estimated effect (circles or square) of 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 lines represent the 95% confidence interval for the estimated effect.

* The estimated effect is statistically significant at the .05 alpha level (two-tailed test).

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