Challenges in Educational Reform:

An Experiment on Active Learning in Mathematics

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Note: The opinions expressed in this presentation are those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors, or the countries they represent.

Motivation

- Cross-country variation in per-capita GPD explained by differences in TFP. This variation arises from:
  - Misallocation of resources (Hsieh and Klenow, 2010)
  - Differences in technology adoption (Foster and Rosenzweig, 2010)

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- Technology adoption in developing countries (examples): fertilizer (Duflo et al., 2009), bed nets (Dupas, 2009), package chlorine (Ashraf et al., 2010), dewarming pills (Miguel and Kremer, 2004), and management practices (Bloom et al. 2013)

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- In education: growing economics literature emphasize necessity of identifying successful pedagogical approaches: Dobbie and Fryer (2013), Fryer (2012), Machin and McNally (2008), Kane et al. (2010, 2012)
  - Experts agree that competence require that students have a more active role in the classroom (US National Councils mathematics reform)
  - Little evidence on which pedagogy works better. No evidence on the adjustment costs of switching pedagogy

Research Questions

1. Can a middle-income developing country (Costa Rica) adopt the pedagogy used in schools in developed countries?
2. Are there *short run* adjustment costs of switching to a new pedagogy?

Experiment

- Salient and significant educational policy: 7th grade Geometry (1 of 3 units of the syllabus - 3 months) in Costa Rica
- 85 schools randomly assigned to 1 of 5 conditions:

Table 1: Experiment

Intervention Group	**Curriculum/ Teaching Approach**	**Technology**
Control	Status-quo (Old)	No
New Curriculum	New	No
Interactive White-board	New	Interactive White-board
Computer Lab	New	Computers (Lab)
One-to-One	New	Computers (One computer per student)

- All 18,000 students and 190 teachers from these schools participated in the experiment

Intervention

- Materials: We commissioned the design of material for this intervention to local experts advised by a leading international education academic organization. Validated by teachers during training.
- For each treatment arm, the team created:
  - Teacher manuals (structure and guidance for the new environments)
  - Student workbooks (hands-on paper-based activities)
  - A set of applets to use with the technology
  - Training modules
- Training: 40 hours. About 1 hour of training per 2 hours of teaching
- Target outcome: knowledge of 7th grade geometry (basic and higher order). Measured using psychometrically valid geometry test

Data

- Intervention affected nearly 18,000 students, 190 teachers in 85 schools. We tested/interviewed/observed 1 classroom (section) per teacher.
- Students:
  - April: International mathematics SAT (SERCE). Baseline student survey.
  - September: Geometry test and student endline survey
- Teachers:
  - May: Baseline survey
  - June, July, August: Teachers logs and Class observations
  - September: Endline survey
- Instruments:
  - Test: Validated geometry test
  - Scales: surveys had questions to compute validated scales to measure class dynamics, beliefs, attitudes, etc.

Empirical Strategy

- We estimate:

$$Y_{ijs} = \alpha_0 + \sum_{k=1}^{2|4} \alpha_k T_{js}^k + \delta_{js} + \beta X_{ijs} + \epsilon_{ijs} \quad (1)$$

  - i=student, j=school, s=strata
  - Dummy T_{js}^k= 1 if the school j in strata s was assigned to treatment:
    - k={1,2}={curriculum, technology}
    - k={1,2,3,4}={curriculum, interactive whiteboard, computer lab, one-to-one}
  - δ_{js} is a set of strata fixed effect
  - X_{ijS} is a vector of student (gender, age, mom education, books, SAT), teacher (gender, age, experience) and school (# students in 7th grade, # classrooms in 7th grade, Lab in school, region dummies) control variables

- s.e. clustered by school

Experiment integrity and internal validity

- Compliance: Table
  - All materials and equipment put in place and functional
  - 95 % of teachers received and passed training
- Non-response rates: Table
  - Very high response rates to tests and survey
  - Teacher logs are "unbalanced" (technology group less likely to be missing
- Pre-treatment balance: Table
  - Treatment and control groups are similar in pre-treatment characteristics
  - Only small differences in age and sex of students in interactive whiteboard schools
- No design gaming: Table
  - Most teachers were assigned to classes before the lottery
  - Most teachers taught geometry during second term

Treatment take-up

All technologies

	Difference w.r.t. Control (coeff and s.e.)		Sample
	Curriculum [1]	Technology [2]	Size [3]
Access/ reported use:			
Class materials	0.764	0.789	190
	[0.066]***	[0.054]***	
Interactive whiteboards	-0.007	0.280	190
	[0.034]	[0.102]***	
Students' laptops	-0.045	0.611	190
	[0.044]	[0.099]***	
Some technology in class	-0.046	0.897	190
	[0.054]	[0.047]***	
Observed use:			
Class uses student's workbook	0.811	0.989	153
	[0.060]***	[0.030]***	
Class uses teacher's manual	0.855	0.966	153
	[0.055]***	[0.036]***	
Class uses Geogebra software	-0.010	0.766	153
	[0.054]	[0.059]***	
Class uses internet	0.004	0.034	153
	[0.014]	[0.022]	
Class uses regular blackboard	-0.267	-0.391	135
	[0.109]**	[0.100]***	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[2] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher, and school controls. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Class dynamics

All technologies

	Difference w.r.t. Control (coeff and s.e.)		Sample
	Curriculum [1]	Technology [2]	Size [3]
Active learning	0.028	0.079	4052
	[0.047]	[0.034]**	
Classroom activity	0.121	0.166	4157
	[0.044]***	[0.038]***	
Exploration	0.310	0.452	153
	[0.080]***	[0.065]***	
Formalization	-0.102	-0.063	153
	[0.041]**	[0.043]	
Practice	-0.208	-0.389	153
	[0.094]**	[0.076]***	
Class plenary lecture	-0.064	-0.055	153
	[0.037]*	[0.033]**	
Class discussion	0.117	0.168	153
	[0.058]**	[0.055]***	
Work in groups	0.010	-0.054	153
	[0.043]	[0.035]	
Work in pairs	0.010	0.004	153
	[0.032]	[0.027]	
Work individually	-0.073	-0.062	153
	[0.059]	[0.060]	
Math prescribed learning practices (Student)	0.300	0.602	153
	[0.253]	[0.207]**	
Math prescribed teaching practices (Teacher)	0.362	0.513	153
	[0.231]	[0.201]**	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[2] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher and school controls. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Did students learn more using this new pedagogy?

Student learning

Geometry Test Results

	Difference w.r.t. Control (coeff. and s.e.)		Sample
	Curriculum [1]	Technology [2]	Size [3]
Geometry score	-0.171	-0.247	4157
	[0.080]**	[0.081]***	
Geometry score (Basic skills)	-0.142	-0.209	4157
	[0.079]*	[0.080]***	
Geometry score (Higher-order skills)	-0.126	-0.204	4157
	[0.054]**	[0.055]***	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[2] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher, and school controls. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Student learning (by technology)

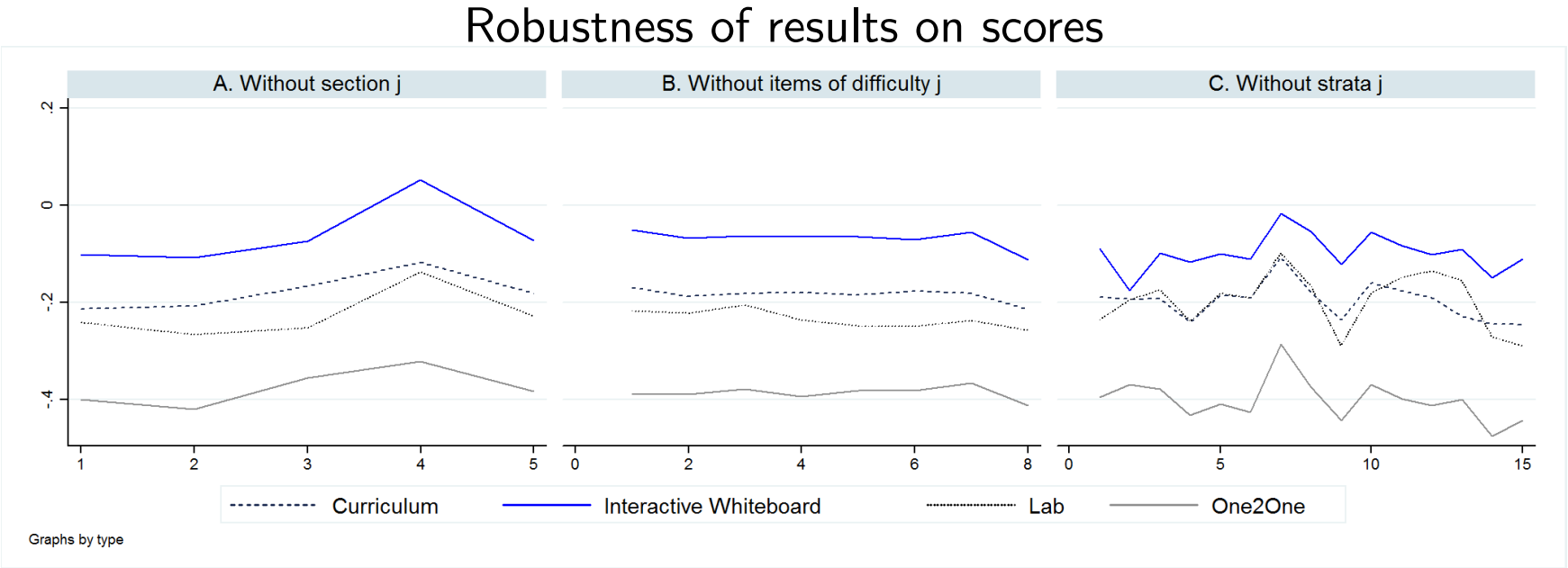
Geometry Test Results

	Difference w.r.t. Control (coeff and s.e.)				
	Curriculum	Interactive Whiteboard	Computer Lab	One-to-One	N
	[1]	[2]	[3]	[4]	[5]
Geometry score	-0.171	-0.155	-0.210	-0.355	4157
	[0.080]**	[0.093]*	[0.118]*	[0.091]***	
Geometry score (Basic skills)	-0.142	-0.090	-0.175	-0.340	4157
	[0.079]*	[0.088]	[0.108]	[0.088]***	
Geometry score (Higher-order skills)	-0.126	-0.138	-0.273	-0.225	4157
	[0.054]**	[0.072]*	[0.086]***	[0.066]***	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[4] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher, and school controls. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1. Column [5] shows the sample size.

▸ Pairwise comparisons

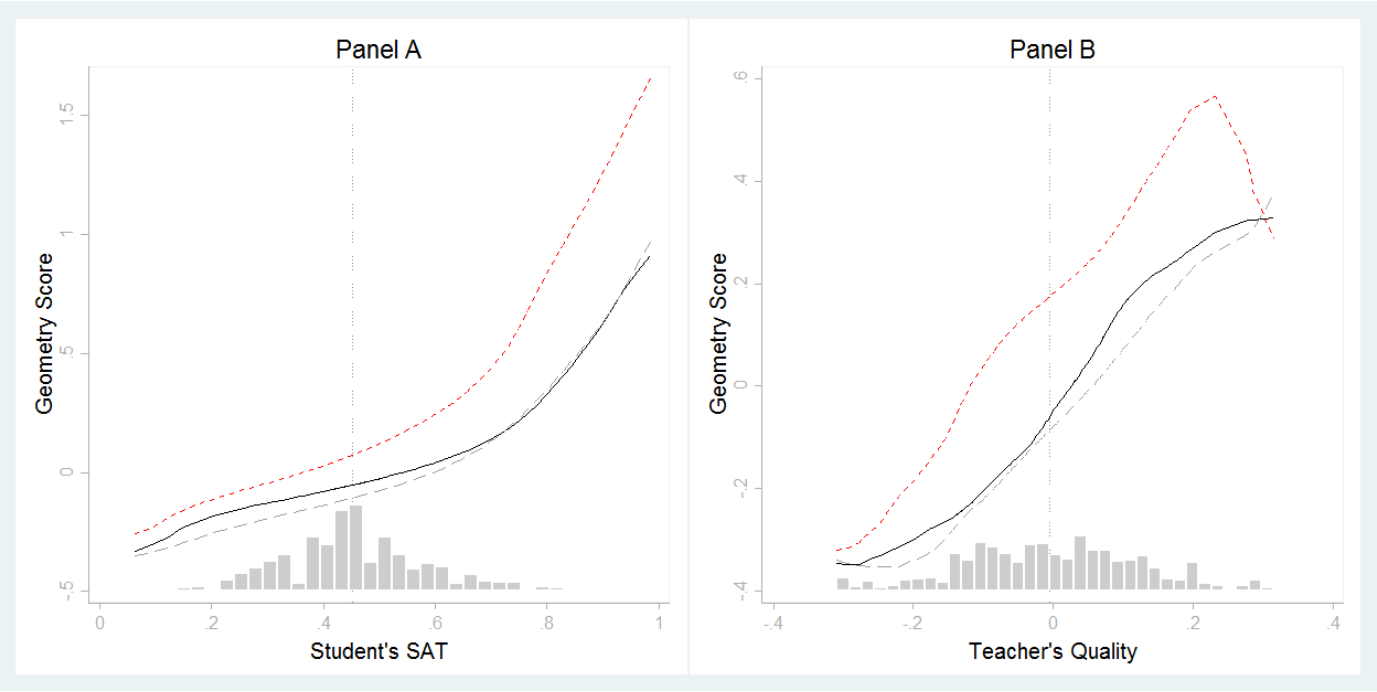
Student learning: Robustness



Note: The y-axis shows the treatment effect of a standardized geometry test score on treatment dummies estimated following equation (2). Panel A shows estimates obtained by removing items that belong to one (syllabus) section at a time. Panel B shows estimates obtained by removing items of one difficulty group at a time. Panel C shows estimates obtained by removing schools in one strata at a time.

Student learning: Heterogeneity

Treatment Effect Heterogeneity (Geometry Score)



Note: Each line presents a local polynomial regression of the geometry test-scores (y-axis) –controlling for strata fixed effects– on a mediating variable (x-axis): student pre-treatment SAT (panel A), teacher experience (panel B) and teacher quality (panel C). The red dashed line is for the control group, the black solid line is for those students in the curriculum condition, and the grey long-dashed line is for those students in the three technology groups. At the bottom of the graph we overlap a histogram of the mediating variable and the vertical line marks the median of the mediating variable distribution. The local polynomial regressions were estimated using an Epanechnikov with a bandwidth of 0.15 (panel A), 2 (panel B) and 0.10 (panel C).

Class mediation: Students

All technologies

	Difference w.r.t. Control (coeff and s.e.)		Sample
	Curriculum [1]	Technology [2]	Size [3]
(A) Bad behavior	0.089	0.071	4030
	[0.056]	[0.054]	
(B) Avoid novelty	0.072	0.085	3943
	[0.053]	[0.048]*	
(C) Academic engagement	-0.040	0.015	3973
	[0.075]	[0.066]	
(D) Academic press	-0.011	-0.033	3917
	[0.048]	[0.039]	
(E) Preference for math	-0.140	-0.055	3970
	[0.077]*	[0.059]	
Student Combined Scale (-A-B+C+D+F)	-0.070	-0.046	3970
	[0.041]*	[0.038]	
Dependent Variable: Student Combined Scale			
Low Ability	-0.034	-0.003	1978
	[0.045]	[0.045]	
High Ability	-0.105	-0.095	1992
	[0.053]**	[0.040]**	

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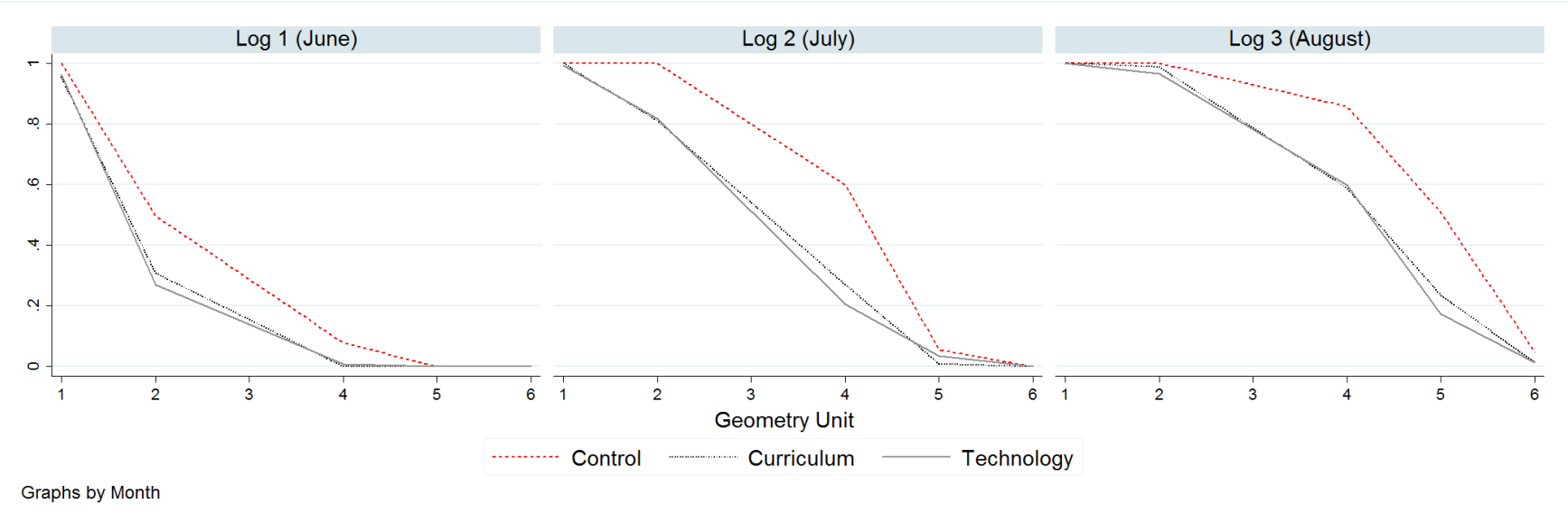
Class mediation: Teachers

All technologies

	Difference w.r.t. Control (coeff and s.e.)		Sample
	Curriculum [1]	Technology [2]	Size [3]
(A) Access to new ideas	0.187	0.374	184
	[0.262]	[0.199]*	
(B) Innovation	0.232	0.076	184
	[0.220]	[0.171]	
(C) Reflective dialogue	0.302	0.417	185
	[0.212]	[0.197]**	
(D) Quality of teacher-student interactions	-0.840	-0.651	153
	[0.384]**	[0.256]**	
(E) Teaching efficacy	-0.198	-0.213	187
	[0.178]	[0.162]	
Teacher Innovation Scale (A+B+C)	0.241	0.289	184
	[0.165]	[0.142]**	
Teacher Mediation Scale (D+F)	-0.519	-0.432	153
	[0.208]**	[0.154]***	
Dependent variable: Innovation Scale			
Low Quality	0.356	0.451	86
	[0.282]	[0.230]**	
High Quality	0.119	0.132	98
	[0.179]	[0.161]	
Dependent variable: Mediation Scale			
Low Quality	-0.521	-0.416	74
	[0.346]	[0.267]	
High Quality	-0.384	-0.339	79
	[0.284]	[0.219]	

Note: Each row shows statistics for a different variable $Y_i sj$ of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[2] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher, and school controls. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Class mediation: Teachers



Note: The y-axis shows the proportion of teachers that completed a given geometry unit (x-axis). Each panel shows this for a different teacher log and point in the calendar (June, July and August).

Conclusion: Findings

- We implemented a large RCT of a salient and policy-relevant educational intervention
  - Material was relevant and validated
  - Teachers valued the material: High take up and changes in class dynamics
  - The experiment was properly implemented (high compliance + integrity + internal validity)
  - The test was valid
- We found short run learning losses:
  - Students using the new curriculum without technology learned 17% of a s.d. less than the status-quo
  - Learning was around 36 % lower in the one laptop per student schools compared to status-quo
- Class mediation failed:
  - We found that the best students were harmed the most (their behavior deteriorated and they were less engaged)
  - We found some evidence of a failure in teaching mediation

Conclusion: Interpretation

- High take up in conjunction with short run learning loses. Will these results persist in the long run?
- Conjectures:
  1. Helpman and Rangel (1999). High take up suggests that teachers observed a positive present value. But there is loss of specific human capital in the short run. In the long run, as teachers mediation improves, learning increases.
  2. Karlan Knight and Udry (2012). High take up is just teachers experimenting. Might not lead to long run gains.
- There are learning costs of educational reform in the short run. Outcomes might improve but requires sustained effort. This should be consider as part of the cost of educational reforms

Thank you!

Compliance: Access to materials, technology and training

- All materials and equipment were in place and functional when the intervention started
- Most teachers received and pass training

Table 2: Compliance

	Classrooms Equipped	Laptop Computers (Students)	Laptop Computers (Teachers)	Laptop Carts (Carritos)	Smartboards	Desktops	Projectors	% Teachers invited to training	% Teachers Trained
Control	0	0	0	0	0	20	20	0%	0%
New Curriculum	0	0	46	0	0	20	20	100%	91%
Interactive White Board	27	0	34	0	27	15	15	100%	97%
Lab	5	77	27	15	0	15	15	100%	100%
One to One	26	784	35	26	0	15	23	100%	94%
Total	58	861	142	41	27	85	93	100%	95%

◂ Integrity/Validity Summary

Back

Scale name and reliability measures [1]		Scale survey question [2]	Factor Loadings [3]
Bad behavior (PALS-UM)	1	Sometimes I bother my teacher during class.	0.6775
	2	Sometimes I get in trouble with my teacher during class.	0.6385
Eigenvalue: 2.124	3	Sometimes I behave in a way that upsets my teacher during class.	0.6154
Cronbach's Alpha: 0.800	4	Sometimes I do not follow my teacher's instructions during class.	0.7239
	5	Sometimes I cause disorder during class.	0.5953
Avoid novelty (PALS-UM)	6	During class I prefer to work on tasks that are familiar to me rather than to learn how to do new ones.	0.2469
	7	I dont like to learn a lot of concepts during class.	0.3265
Eigenvalue: 0.896	8	I prefer to do my work as usual rather than to try something new.	0.4208
Cronbach's Alpha: 0.542	9	I like academic concepts that are familiar to me rather than ones I have never heard before.	0.4747
	10	I would rather chose to work on something I already know how to do rather than something I have never done before.	0.5711
Academic engagement (Chicago)	11	I often count down the minutes until class is over.	-0.4517
	12	What I am learning in class is so interesting, I dont want class to end.	0.6685
Eigenvalue: 1.72	13	I usually look forward to this class.	0.7009
Cronbach's Alpha: 0.678	14	I usually get bored with what we are learning in class.	-0.4733
	15	The topics we are studying are interesting and challenging.	0.5231
	16	I work hard to do my best in this class.	0.2916
Academic press (Chicago)	17	Nobody wastes time in class.	0.0870
	18	Usually this is a difficult class.	0.1833
Eigenvalue: 1.531	19	Usually the teacher asks difficult questions in class.	0.2144
Cronbach's Alpha: 0.638	20	Usually the teacher asks difficult questions on tests.	0.2241
	21	Usually this class challenges me.	0.4187
	22	This class really makes me think.	0.4070
	23	Generally this class requires me to work hard to do well.	0.2865
	24	The teacher expects everyone do their best all the time.	0.7205
	25	The teacher expects everyone to work hard.	0.6723
Preference for math (SRI)	26	How much do you like mathematics?	0.7040
Eigenvalue: 1.925	27	Think about the most recent unit in your math class. Think about the activities and the math you learned. How much did you enjoy your math class during this unit?	0.8922
Cronbach's Alpha: 0.827	28	Think about the most recent unit in your math class. If math classes were always like this, would you be excited to take math classes in the future?	0.7961

Back

Scale name and reliability measures [1]		Scale survey question [2]	Factor Loadings [3]
Access to New Ideas (Chicago)		Usually	
	1	I have discussed curriculum/instruction matters with an outside group	0.2069
Eigenvalue: 2.196	2	I have attended professional development activities organized by my school	0.3366
Cronbach's Alpha: 0.756	3	I have taken college/university courses relative to improving my school	0.3143
	4	I have participated in a network with teachers outside my school	0.4769
	5	I have worked with other teachers to develop materials or activities for specific classes	0.8238
	6	I have observed another teacher's class to obtain ideas about how to teach my class	0.2865
	7	I have reviewed my students' evaluations with other teachers to make decisions about teaching	0.4554
	8	I have observed another teacher's class to provide them with feedback	0.5530
	9	I have worked on teaching strategies with other teachers	0.6633
Innovation (Chicago)		The teachers in this school	
	10	Are really trying to improve their teaching	0.7910
Eigenvalue: 1.986	11	Are willing to take risks to make the school better	0.4675
Cronbach's Alpha: 0.823	12	Are eager to try new ideas	0.5954
	13	Have a positive "I can do" attitude	0.5695
	14	Are continually learning and seeking new ideas	0.4747
	15	Are encouraged to "grow" professionally	0.4877
Reflective dialogue (Chicago)		In this school year, have you had conversations with your colleagues more than twice about	
	16	What helps students learn the best	0.7587
Eigenvalue: 4.204	17	The mathematics curriculum	0.7635
Cronbach's Alpha: 0.847	18	The goals of this school	0.6615
	19	Managing classroom behavior	0.7542
	20	Teaching styles and learning	0.6942
	21	Teachers in this school discuss instruction in the teachers' lounge, faculty meetings, etc	0.7616
	22	Teachers in this school share and discuss student work with other teachers	0.7200
	23	Experienced teachers invite new teachers to observe their class, provide feedback, etc	0.4446
	24	The teacher body at this school makes new teachers feel welcomed	0.5108
Teacher mediation		Mark if you observe or don't the following teacher-students interactions:	
(Class observations)	25	Maintain class order/discipline	0.6031
Eigenvalue: 1.007	26	Offers students clear instructions	0.5533
Cronbach's Alpha: 0.454	27	Answer students questions	-0.0871
	28	Students follow instructions without difficulty	0.5696
	29	Students ask questions when they need to	0.0712
Teaching efficacy (Chicago)	30	With enough effort I can even make students with the most difficulty understand the subject	0.5199
	31	Events I can not control have a greater influence on the performance of my students than I do	-0.0341
Eigenvalue: 1.786	32	I am good at helping my students achieve significant improvements	0.8185
Cronbach's Alpha: 0.563	33	Some students will not make much progress this year, regardless of what I do	0.1693
	34	I am sure I can make a difference in the lives of my students	0.6724
	35	There is little I can do to ensure that all my students achieve significant progress this year	-0.0957
	36	I perform well under any teaching challenge	0.5959

Balance

◀ Integrity/Validity Summary

	Average and s.d. All [1]	Difference w.r.t. Control (coeff and s.e.) Curriculum [2]	Technology [3]	p-value [4]	Sample Size [5]
Student-level Variables					
Percent Male	0.489	-0.029	-0.018	0.520	4157
	[0.500]	[0.019]	[0.018]		
Age (years)	12.970	0.072	-0.022	0.087	4127
	[0.878]	[0.061]	[0.041]		
Mother's Education (Primary)	0.419	0.046	0.010	0.329	4106
	[0.493]	[0.044]	[0.043]		
Mother's Education (Secondary)	0.406	0.003	0.008	0.844	4106
	[0.491]	[0.025]	[0.025]		
Number of Books at home	3.161	-0.085	-0.052	0.659	3560
	[1.565]	[0.083]	[0.094]		
Have a PC/laptop at home	0.735	-0.033	-0.004	0.342	3543
	[0.442]	[0.036]	[0.031]		
SAT (% Correct)	0.466	-0.019	-0.008	0.380	3278
	[0.145]	[0.017]	[0.017]		
Teacher Level Variables					
Percent Male	0.486	0.029	0.146	0.236	185
	[0.501]	[0.127]	[0.102]		
Age (years)	36.668	0.853	0.104	0.560	184
	[7.772]	[1.385]	[1.122]		
Experience (years)	11.652	0.500	0.400	0.925	184
	[6.543]	[1.251]	[0.950]		
School-Level Variables					
Students 7th Grade	219.694	-0.650	-1.065	0.980	85
	[114.174]	[16.949]	[8.923]		
Classes 7th Grade	6.847	-0.000	-0.194	0.583	85
	[3.053]	[0.380]	[0.259]		
Computer Lab	0.741	-0.000	-0.017	0.891	85
	[0.441]	[0.148]	[0.124]		
Internet in School	0.729	0.150	-0.010	0.141	85
	[0.447]	[0.136]	[0.129]		
7th Grade Repetition	0.087	-0.018	-0.011	0.709	85
	[0.062]	[0.020]	[0.016]		
Not Urban	0.447	-0.050	-0.068	0.888	85
	[0.500]	[0.148]	[0.121]		

Balance

◂ Integrity/Validity Summary

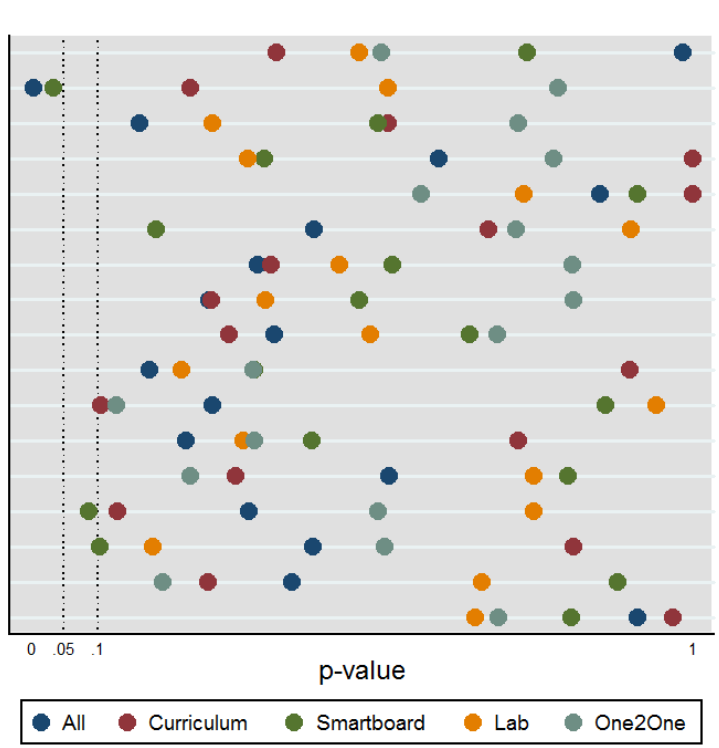
	Average and s.d. All	Difference w.r.t. Control (coeff and s.e.)				p-value	Sample Size
		Curriculum	Interactive Whiteboard	Computer Lab	One-to-One		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Student-level Variables							
Percent Male	0.489	-0.029	-0.038	0.008	-0.016	0.330	4157
	[0.500]	[0.019]	[0.022]*	[0.026]	[0.025]		
Age (years)	12.970	0.072	-0.093	0.032	0.015	0.004	4127
	[0.878]	[0.061]	[0.043]**	[0.052]	[0.058]		
Mother's Education (Primary)	0.419	0.046	-0.021	0.042	0.019	0.368	4106
	[0.493]	[0.044]	[0.048]	[0.064]	[0.050]		
Mother's Education (Secondary)	0.406	0.003	0.026	-0.045	0.030	0.180	4106
	[0.491]	[0.025]	[0.027]	[0.037]	[0.031]		
Number of Books at home	3.161	-0.085	-0.024	0.038	-0.151	0.541	3560
	[1.565]	[0.083]	[0.100]	[0.124]	[0.128]		
Have a PC/laptop at home	0.735	-0.033	0.020	-0.033	-0.009	0.342	3543
	[0.442]	[0.036]	[0.033]	[0.045]	[0.039]		
SAT (% Correct)	0.466	-0.019	0.003	-0.007	-0.022	0.394	3278
	[0.145]	[0.017]	[0.021]	[0.017]	[0.017]		
Teacher Level Variables							
Percent Male	0.486	0.029	0.181	0.201	0.076	0.426	185
	[0.501]	[0.127]	[0.110]*	[0.150]	[0.122]		
Age (years)	36.668	0.853	0.799	-1.359	0.490	0.165	184
	[7.772]	[1.385]	[1.248]	[1.234]	[1.452]		
Experience (years)	11.652	0.500	1.414	0.154	-0.389	0.428	184
	[6.543]	[1.251]	[1.070]	[1.293]	[1.138]		
School-Level Variables							
Students 7th Grade	219.694	-0.650	-2.643	-5.310	4.757	0.916	85
	[114.174]	[16.949]	[11.334]	[12.440]	[12.564]		
Classes 7th Grade	6.847	-0.000	-0.306	-0.372	0.094	0.616	85
	[3.053]	[0.380]	[0.327]	[0.378]	[0.350]		
Computer Lab	0.741	-0.000	-0.017	0.050	-0.083	0.859	85
	[0.441]	[0.148]	[0.161]	[0.153]	[0.153]		
Internet in School	0.729	0.150	0.101	-0.165	0.035	0.270	85
	[0.447]	[0.136]	[0.148]	[0.177]	[0.153]		
7th Grade Repetition	0.087	-0.018	-0.008	-0.013	-0.012	0.984	85
	[0.062]	[0.020]	[0.025]	[0.019]	[0.019]		
Not Urban	0.447	-0.050	0.110	-0.157	-0.157	0.235	85
	[0.500]	[0.148]	[0.137]	[0.157]	[0.163]		

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Column [1] shows the sample average and the standard deviation in square brackets. Columns [2]-[5] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model that only include controls for strata. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column [6] shows the p-value of a test of all coefficients jointly equal to zero. Column [7] shows the sample size.

Balance

◂ Integrity/Validity Summary

Outcome	T	C	N
7th grade repetition	0.084	0.096	85
Age (Students)	12.972	12.965	4127
Age (Teachers)	36.951	35.714	184
Classes 7th grade	6.846	6.850	85
Computer lab	0.738	0.750	85
Experience	11.709	11.465	184
Have a PC/laptop at home	0.731	0.748	3543
Internet in school	0.738	0.700	85
Mother's education (primary)	0.422	0.409	4106
Mother's education (secondary)	0.407	0.402	4106
Mother's education (university)	0.171	0.189	4106
Not urban	0.431	0.500	85
Number of books at home	3.151	3.193	3560
Percent Male (Students)	0.484	0.505	4157
Percent Male (Teachers)	0.507	0.419	185
SAT (% Correct)	0.464	0.476	3278
Students 7th grade	220.200	218.050	85



Note: Column Outcome shows the covariate, column T the mean among the treated (curriculum, interactive whiteboard, lab and one-to-one schools), column C the mean among the controls, column N the sample size. Each dot is the p-value of the t-test of the null hypothesis that the regression coefficient in equation (1) is equal to zero. The dots labeled All show the p-value of the null that all four point estimates are jointly equal to zero.

Non-response rates

Integrity/Validity Summary

	Average and S.D. All [1]	Difference w.r.t. Control (coeff and s.e.) Curriculum [2]	Technology [3]	p-value [4]	Sample Size [5]
Student Level Variables					
Missing on Geo test day	0.091	-0.017	0.008	0.217	4625
	[0.288]	[0.024]	[0.018]		
Geo test date (# days after end of geo unit)	6	1.813	-0.323	0.203	4157
	[6.489]	[1.971]	[1.815]		
Missing SAT (among eligible students)	0.211	-0.027	-0.098	0.256	4157
	[0.408]	[0.091]	[0.070]		
Student with disability (did not take geo test)	0.011	-0.010	-0.017	0.323	4881
	[0.103]	[0.012]	[0.011]		
Teacher Level Variables					
Missing teacher survey (baseline)	0.005	-0.025	-0.021	0.472	190
	[0.073]	[0.019]	[0.015]		
Missing teacher survey (endline)	0.032	0.003	-0.012	0.623	190
	[0.175]	[0.035]	[0.031]		
Missing class observation	0.195	0.027	-0.059	0.267	190
	[0.397]	[0.095]	[0.072]		
Missing teacher log June	0.111	-0.022	-0.163	0.129	190
	[0.314]	[0.127]	[0.092]*		
Missing teacher log July	0.163	-0.147	-0.192	0.464	190
	[0.370]	[0.082]*	[0.068]***		
Missing teacher log August	0.237	-0.102	-0.175	0.441	190
	[0.426]	[0.101]	[0.073]**		

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Column [1] shows the sample average and the standard deviation in square brackets. Columns [2]-[3] show the regression coefficients and the standard errors in square brackets

Non-response rates

◂ Integrity/Validity Summary

	Average and S.D. All	Difference w.r.t. Control (coeff and s.e.)				p-value	Sample Size
		Curriculum	Interactive Whiteboard	Computer Lab	One-to-One		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Student Level Variables							
Missing on Geo test day	0.091	-0.017	-0.008	0.029	0.009	0.201	4625
	[0.288]	[0.024]	[0.021]	[0.022]	[0.026]		
Geo test date (# days after end of geo unit)	6	1.813	-0.963	2.367	-1.675	0.094	4157
	[6.489]	[1.971]	[1.956]	[1.902]	[2.419]		
Missing SAT (among eligible students)	0.211	-0.027	-0.084	-0.138	-0.083	0.572	4157
	[0.408]	[0.091]	[0.070]	[0.084]*	[0.079]		
Student with disability (did not take geo test)	0.011	-0.010	-0.018	-0.020	-0.014	0.585	4881
	[0.103]	[0.012]	[0.012]	[0.012]*	[0.011]		
Teacher Level Variables							
Missing teacher survey (baseline)	0.005	-0.025	-0.020	-0.021	-0.020	0.902	190
	[0.073]	[0.019]	[0.015]	[0.016]	[0.015]		
Missing teacher survey (endline)	0.032	0.003	0.016	-0.046	-0.013	0.304	190
	[0.175]	[0.035]	[0.038]	[0.038]	[0.033]		
Missing class observation	0.195	0.027	-0.003	-0.041	-0.127	0.117	190
	[0.397]	[0.095]	[0.088]	[0.102]	[0.072]*		
Missing teacher log June	0.111	-0.022	-0.142	-0.216	-0.145	0.288	190
	[0.314]	[0.127]	[0.100]	[0.102]**	[0.095]		
Missing teacher log July	0.163	-0.147	-0.244	-0.242	-0.105	0.145	190
	[0.370]	[0.082]*	[0.074]***	[0.087]***	[0.081]		
Missing teacher log August	0.237	-0.102	-0.217	-0.162	-0.143	0.709	190
	[0.426]	[0.101]	[0.088]**	[0.107]	[0.093]		

Gaming

◂ Integrity/Validity Summary

	Average and S.D.	Difference w.r.t. Control (coeff and s.e.)		p-value	Sample
	All	Curriculum	Technology		Size
	[1]	[2]	[3]	[4]	[5]
Learned teaching assignment before lottery	0.837	-0.106	-0.054	0.441	190
	[0.370]	[0.079]	[0.064]		
Class learned geometry 1st Term	0.016	-0.020	-0.041	0.337	190
	[0.125]	[0.050]	[0.044]		
Class learned 4 geo units in 1st Term	0.126	0.066	-0.080	0.067	190
	[0.333]	[0.122]	[0.094]		

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Column [1] shows the sample average and the standard deviation in square brackets. Columns [2]-[3] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model that only include controls for strata. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column [4] shows the p-value of a test of all coefficients jointly equal to zero. Column [5] shows the sample size.

Gaming

◂ Integrity/Validity Summary

	Average and S.D.	Difference w.r.t. Control (coeff and s.e.)				p-value	Sample
	All	Curriculum	Interactive Whiteboard	Computer Lab	One-to-One		Size
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Learned teaching assignment before lottery	0.837	-0.106	-0.118	0.035	-0.055	0.285	190
	[0.370]	[0.079]	[0.084]	[0.082]	[0.079]		
Class learned geometry 1st Term	0.016	-0.020	-0.045	-0.037	-0.041	0.794	190
	[0.125]	[0.050]	[0.049]	[0.041]	[0.044]		
Class learned 4 geo units in 1st Term	0.126	0.066	-0.034	-0.092	-0.117	0.113	190
	[0.333]	[0.122]	[0.109]	[0.098]	[0.094]		

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Column [1] shows the sample average and the standard deviation in square brackets. Columns [2]-[5] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model that only include controls for strata. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column [6] shows the p-value of a test of all coefficients jointly equal to zero. Column [7] shows the sample size.

Treatment take-up

Back

	Difference w.r.t. Control (coeff and s.e.)				
	Curriculum [1]	Interactive Whiteboard [2]	Computer Lab [3]	One-to-One [4]	N [5]
Access/ reported use:					
Class materials	0.764	0.897	0.854	0.664	190
	[0.066]***	[0.052]***	[0.083]***	[0.073]***	
Interactive whiteboards	0.002	0.963	-0.044	-0.052	190
	[0.034]	[0.026]***	[0.028]	[0.027]	
Students' laptops	-0.047	-0.044	0.949	0.925	190
	[0.043]	[0.045]	[0.045]***	[0.054]***	
Some technology in class	-0.046	0.919	0.905	0.873	190
	[0.054]	[0.052]***	[0.052]***	[0.056]***	
Observed use:					
Class uses student's workbook	0.811	1.017	0.934	0.995	153
	[0.060]***	[0.033]***	[0.074]***	[0.035]***	
Class uses teacher's manual	0.855	0.995	0.906	0.973	153
	[0.055]***	[0.049]***	[0.098]***	[0.045]***	
Class uses Geogebra software	-0.010	0.804	0.552	0.844	153
	[0.054]	[0.073]***	[0.097]***	[0.074]***	
Class uses internet	0.004	0.006	0.014	0.067	153
	[0.014]	[0.017]	[0.019]	[0.043]	
Class uses regular blackboard	-0.267	-0.255	-0.417	-0.499	135
	[0.109]*	[0.140]	[0.139]**	[0.099]***	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[4] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual,

Class dynamics

Back

	Difference w.r.t. Control (coeff and s.e.)				
	Curriculum	Interactive Whiteboard	Computer Lab	One-to-One	N
	[1]	[2]	[3]	[4]	[5]
Active learning	0.028	0.093	0.049	0.084	4052
	[0.047]	[0.044]**	[0.053]	[0.037]**	
Classroom activity	0.121	0.223	0.117	0.141	4157
	[0.044]***	[0.049]***	[0.051]**	[0.053]***	
Exploration	0.310	0.388	0.546	0.456	153
	[0.080]***	[0.070]***	[0.089]***	[0.075]***	
Formalization	-0.102	-0.047	-0.081	-0.068	153
	[0.041]**	[0.051]	[0.050]	[0.051]	
Practice	-0.208	-0.341	-0.465	-0.389	153
	[0.094]**	[0.090]***	[0.094]***	[0.086]***	
Class plenary lecture	-0.064	-0.107	-0.051	-0.014	153
	[0.037]*	[0.033]***	[0.049]	[0.034]	
Class discussion	0.117	0.315	0.125	0.067	153
	[0.058]**	[0.060]***	[0.074]*	[0.058]	
Work in groups	0.010	-0.052	0.016	-0.092	153
	[0.043]	[0.042]	[0.042]	[0.036]**	
Work in pairs	0.010	0.015	0.050	-0.030	153
	[0.032]	[0.034]	[0.037]	[0.028]	
Work individually	-0.073	-0.172	-0.140	0.069	153
	[0.059]	[0.066]***	[0.086]	[0.060]	
Math prescribed learning practices (Student)	0.300	0.578	0.439	0.706	153
	[0.253]	[0.230]**	[0.293]	[0.259]**	
Math prescribed teaching practices (Teacher)	0.362	0.426	0.576	0.553	153
	[0.234]	[0.240]	[0.309]*	[0.236]**	

Note: Each row shows statistics for a different variable Y_{isj} of individual (student, teacher or school) i, in strata s and in school j. Columns [1]-[4] show the regression coefficients and the standard errors in square brackets corresponding to equation (1), a regression model which includes strata, individual, teacher, and school controls. Standard errors are clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column [5] shows the sample size.

Student learning: Comparisons

Learning

- **Intervention groups comparisons:** For any two groups we can test H_0: $\beta_g = \beta_{g'}$, vs the (one side) alternative H_1: $\beta_g < \beta_{g'}$

One Side Tests

Dependent Variable:	Without Controls	With Controls
p-values of one side test H1:	[1]	[2]
One2One <= Lab	0.055	0.093
One2One <= Curriculum	0.008	0.008
One2One <= Interactive whiteboard	0.002	0.012
Lab <= Interactive board	0.225	0.320
Lab <= Curriculum	0.500	0.366
Curriculum <= Interactive whiteboard	0.119	0.411

Note: standard errors in brackets are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1. Individual controls include gender, age, mom educ, books, SAT. Teacher controls include gender, age, experience. School controls include # students in 7th grade, # classrooms in 7th grade, Lab in school, region dummies. Dependent variables: score is the % correct score and standardized IRT-score (was produced using the IRT parameteres in the control sample.) Both scores are standardizes using mean and s.d. of the control.

Class mediation: Students

Back

	Difference w.r.t. Control (coeff and s.e.)				
	Curriculum	Interactive Whiteboard	Computer Lab	One-to-One	N
	[1]	[2]	[3]	[4]	[5]
(A) Bad behavior	0.089	0.096	0.002	0.090	4030
	[0.056]	[0.056]*	[0.063]	[0.066]	
(B) Avoid novelty	0.072	0.050	0.092	0.115	3943
	[0.053]	[0.053]	[0.065]	[0.061]*	
(C) Academic engagement	-0.040	0.047	-0.003	-0.003	3973
	[0.075]	[0.078]	[0.085]	[0.085]	
(D) Academic press	-0.011	-0.048	-0.014	-0.030	3917
	[0.048]	[0.046]	[0.046]	[0.047]	
(E) Preference for math	-0.140	-0.025	-0.085	-0.066	3970
	[0.077]*	[0.068]	[0.076]	[0.076]	
Student Combined Scale (-A-B+C+D+F)	-0.070	-0.034	-0.039	-0.061	3970
	[0.041]*	[0.041]	[0.045]	[0.053]	
Dependent Variable: Student Combined Scale					
Low Ability	-0.034	-0.003	-0.020	0.006	1978
	[0.045]	[0.053]	[0.049]	[0.061]	
High Ability	-0.105	-0.077	-0.052	-0.138	1992
	[0.053]**	[0.044]*	[0.052]	[0.050]***	

Class mediation: Teachers

Back

	Difference w.r.t. Control (coeff and s.e.)				
	Curriculum	Interactive Whiteboard	Computer Lab	One-to-One	N
	[1]	[2]	[3]	[4]	[5]
(A) Access to new ideas	0.187	0.284	0.511	0.373	184
	[0.262]	[0.255]	[0.280]*	[0.225]	
(B) Innovation	0.232	0.018	-0.053	0.197	184
	[0.220]	[0.232]	[0.225]	[0.221]	
(C) Reflective dialogue	0.302	0.378	0.468	0.420	185
	[0.212]	[0.227]*	[0.237]**	[0.213]**	
(D) Quality of teacher-students interactions	-0.840	-0.544	-1.262	-0.422	153
	[0.384]*	[0.311]	[0.500]**	[0.281]	
(E) Teaching efficacy	-0.198	-0.150	-0.185	-0.278	187
	[0.201]	[0.234]	[0.244]	[0.195]	
Teacher Innovation Scale (A+B+C)	0.241	0.227	0.309	0.330	184
	[0.165]	[0.172]	[0.185]*	[0.157]**	
Teacher Mediation Scale (D+F)	-0.519	-0.347	-0.723	-0.350	153
	[0.208]**	[0.192]*	[0.249]***	[0.160]**	
Dependent variable: Innovation Scale					
Low Quality	0.356	0.564	0.272	0.498	86
	[0.282]	[0.314]*	[0.300]	[0.241]**	
High Quality	0.119	0.027	0.366	0.120	98
	[0.179]	[0.216]	[0.208]*	[0.217]	
Dependent variable: Mediation Scale					
Low Quality	-0.521	-0.023	-0.879	-0.419	74
	[0.346]	[0.358]	[0.357]**	[0.308]	
High Quality	-0.384	-0.443	-0.375	-0.179	79
	[0.284]	[0.283]	[0.407]	[0.227]	

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