Identifying and Nurturing Math Talent:

Evidence from Tamil Nadu

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Intro: Motivation

Developing talent has private and social benefits: talented individuals make many contributions to science, engineering, entrepreneurship, education, etc.

There is substantial missing talent from well-resourced communities, but gaps are particularly stark in many cross-country and demographic comparisons.

India offers many striking examples:

- Fewer than 5% of students at the 23 Indian Institutes of Technology (IITs) are thought to come from government schools.
- There is a large gender gap at elite schools: The IITs are 20% female.
- PISA reported that the 95th percentile 15-year-old Tamil Nadu government school student had math knowledge around the US median.

The development literature has noted that India's rigid curriculum may leave many struggling students behind. Much less attention has been paid to whether it also fails to develop those at the top.

Intro: Motivation

More concretely, GHSS Kuntrathur Girls has about 2000 female students. Almost surely, the number who reach an IIT will be zero.

Intro: Challenges

Developing the STEM talent in Indian government schools will require overcoming many challenges.

- Schools lack the scale/resources to offer gifted programs.
- Parents have limited ability to help.
- Rural students lack access to tutoring (and couldn't afford it).
- Limited access to online resources.
- English skills further limit resource accessibility.
- Math skills well behind comparably able US students.

It seems implausible that these challenges can be overcome other than via a sustained multi-year effort.

Fortunately, the Tamil Nadu government is interested in talent development.

Intro: Long Term Plans

At the broadest level we investigate whether the availability of advanced online material makes it possible to nurture talented students in resource-poor settings.

More narrowly, we hypothesize that many Tamil Nadu government-school students could be helped by a multi-year program with a particular structure.

- Use administrative data and teacher recommendations to identify a very large set of 7th graders as potential candidates.
- Provide potential candidates with (cheap) sample content. Use engagment and other data to select RCT sample.
- Take an aggressive approach with the RCT sample: (randomly) provide students with a challenging online math course designed for US students with stronger backgrounds. Also provide cellular-enabled tablets and various supports.
- Use performance in the online course to select students for a program involving multiple years of coursework and support.

Intro: Main Questions

This paper uses data from the first phase of our RCT to address three questions relevant to the broad and narrow hypotheses.

1. **Can we find a substantial number of students with the ability/interest/grit to succeed in courses designed for advanced US students** and provide them (at scale) with infrastructure and support sufficient to do so?
2. How can one **best identify** students well-matched to such a program?
3. What **support** features are important for making such a program work?

Our design cross-randomizes the main treatment with many subtreatments to provide insights on identification and support.

We'll also have a number of other observations.

Experiment: Setting

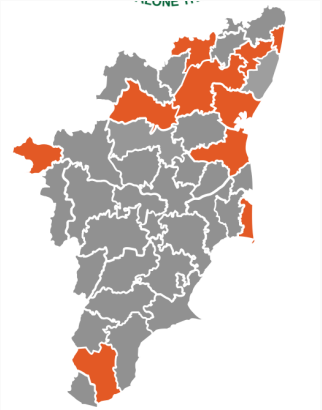
Tamil Nadu is India's 6th largest state.

Less than half of its ≈1 million 7th graders attend government schools.

There are large disparities between government vs. private schools and between government schools in wealthy urban vs. all other areas.

We are working in ten districts, mostly in rural areas, but with a few in poor urban areas.

Almost all of our students are disadvantaged to some degree. The median father is a daily-wage worker with a 10th grade education. Almost all belong to a scheduled caste or tribe or some other "backward class".



Districts in Tamil Nadu: Chennai, Kancheepuram, Tiruvannamalai, Viluppuram, Cuddalore, Dharmapuri, Nagapattinam, Tirunelveli, Nilgiri, and Vellore

Experiment: Selection Procedure

The School Education Department provided 6th grade end-of-year exam scores for 112,630 7th grade students at 3,494 government schools.

We planned visits to 1,441 schools with ≥ 2 high scorers or 1 very high scorer. We provided a booklet containing the first chapter of our course textbook to 9,709 students: 7,272 we selected plus 2,437 recommended by teachers.

We gathered booklet engagement data in two ways: teachers sent photos of answer pages; and students could answer questions online.

A month later students took an online quiz that tested booklet material and assessed "grit". We did not send staff back for this. About 70% cheated.

We selected 2490 students for the RCT using eight (randomized) methods. All weighted four variables: *Admin*, *Booklet*, *Quiz*, *Grit*.

Experiment: Selected Students

Some facts on the sample:

- We select about 3.4% of students at visited schools.
- Most have 95th percentile math scores.
- At each stage the sample becomes somewhat less disadvantaged.
- The RCT sample is two-thirds girls!

	(1) All Students	(2) Selected for Screening	(3) Selected for RCT
Male	0.484	0.371	0.332
Scheduled Caste/Tribe	0.381	0.279	0.236
English-medium	0.330	0.367	0.443
Father's Employment Type			
Daily Wage	0.781	0.720	0.654
Private	0.081	0.102	0.135
Government	0.009	0.020	0.028
Father's Education Level			
5th Grade and below	0.179	0.126	0.113
8th Grade	0.250	0.219	0.181
10th Grade	0.404	0.414	0.405
12th Grade and above	0.167	0.242	0.301
6th-grade Math Score	66.09	83.22	89.52
6th-grade Math (in-school z)	0.00	1.40	1.69
Num. Students	112,630	9,709	2,490
Num. Schools	3,494	1,355	867

Experiment: Selected Students

The median visited school has one student selected. The median treatment student has three classmates in the program.

Experiment: Treatment

We randomize treatment at the school level. Two thirds receive:

- Internet-connected Android tablet.
- Subscription to a challenging self-paced online math course: AoPS's *PreAlgebra 1*.
- Assistance with initial course setup.
- Periodic messaging in a WhatsApp group (with other students from area) encouraging progress.
- Various randomized supports: tutoring, access to school computer lab, threats to reclaim tablets.

Experiment: Math Course

The Art of Problem Solving (AoPS) was founded by math olympiad winners.

Its courses are popular among students preparing for math competitions and parents who want to supplement what their kids get in (well-resourced) schools.

The *PreAlgebra 1* course has 366 components including:

- Engaging video lectures
- Written lessons
- Adaptive “Alcumus” quizzes assessing 36 topics
- 144 non-adaptive challenge problems

Alcumus quizzes can sometimes be passed by answering as few as two questions, but one student never passed one quiz despite correctly answering 145 questions. Students can also aspire to “master” quizzes.

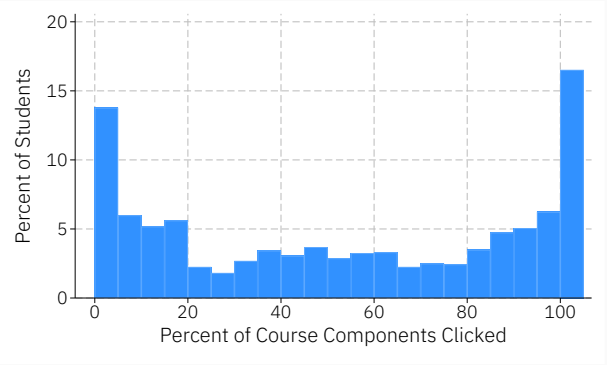
We get remarkably detailed individual-level data on course performance.

Results: Student Engagement

Our most fundamental question is whether it is possible to find a substantial number of students with the ability/interest/grit to jump into AoPS *PreAlgebra 1*.

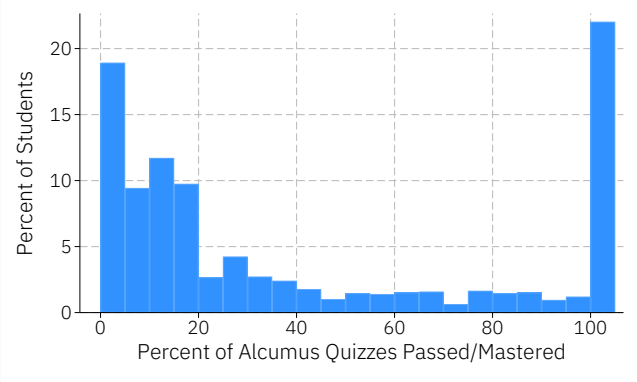
We get a strong yes on engagement!

- 36% of students **invited to participate** clicked on at least 80% of course components.
- 17% click on all 366 components.



Results: Student Learning

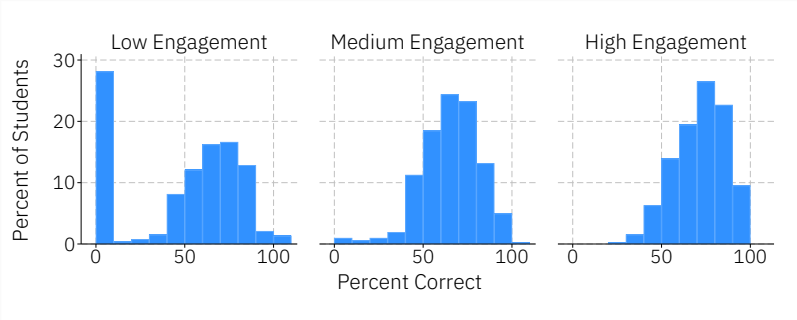
Alcumus quizzes demonstrate that students learned the material: 22% of students passed all 36 Alcumus quizzes.



A few highly engaged students didn't do many quizzes.

Results: Student Learning

Alcumus's adaptive difficulty is impressive. We infer it targets students getting 75%. Its ability to adapt may help our students make up for their deficits.



The course difficulty still seems to have overwhelmed some students.

Our grittiest student attempted 8,098 Alcumus questions (getting 3,693 correct). They eventually "mastered" 23 topics and "passed" the other 13.

Results: Student Learning

Our analyses of program design will consider multiple engagment/learning measures.

One simple measure we'll use often is a dummy variable we call *Successful Completion*:

- Click on 80% of course components.
- Pass at least 90% of Alcumus quizzes.
- Solve at least 60% of viewed Challenge problems.

326 treatment students reached this benchmark.

This is 20.3% of the students that we invited to participate!

தமிழ் சுடர்

நான்குநேரி ஒன்றியம் கூந்தன்குளம் அரசு பள்ளி மாணவிகள்

மாநில அளவில் நடந்த கணிதத் திறமை போட்டியில் வெற்றி பெற்று சாதனை

நான்குநேரி,பிப்.15–

நெல்லை மாவட்டம் நாங்குநேரி ஒன்றியம் கூந்தன்குளம் அரசு நடுநிலைப் பள்ளி ஏழாம் வகுப்பு படிக்கும் மாணவிகள் வெ.கோகிலா மற்றும் பா.சங்கீதா . இவர்கள் தமிழ்நாடு அரசு பள்ளிக் கல்வித்துறை மற்றும் ஜேபால் சவுத் ஆசியா நிறுவனம் இணைந்து மாநில அளவில் இணைய தளம் மூலம் நடத்திய "கணிதத் திறமை" போட்டியில் பங்கு பெற்று வெற்றி பெற்றனர்.

இவர்களுக்கு போட்டிகள் நடத்திய ஜேபால் நிறுவனம் வழங்கிய டேப்லெட் மற்றும் சிம் கார்டு ஆகியவற்றை பள்ளி தலைமை ஆசிரியர் ஜே.ஜோனாத்தான் மற்றும் கணித ஆசிரியர்கள் சங்கரநாராயணன் , ஜேபால் நிறுவனத்தின் கள ஆய்வாளர் சுரேந்திரன் ஆகியோர் வழங்கி பாராட்டினர். நிகழ்ச்சியில் மாணவிகளின் பெற்றோர்கள் கலந்து கொண்டனர்.

வெற்றி பெற்ற மாணவிகளையும் அதற்கு உறுதுணையாக இருந்த பள்ளி தலைமை ஆசிரியர் மற்றும் கணித ஆசிரியரை நான்குநேரி வட்டார கல்வி அலுவலர் சங்கீதா பாராட்டினார்.

நான்குநேரி ஒன்றியம், கூந்தன்குளம் அரசு பள்ளி மாணவிகள் மாநில அளவில் நடந்த கணிதத் திறமை போட்டியில் வெற்றி பெற்று சாதனைபடைத்த மாணவிகளை பள்ளி தலைமை ஆசிரியர் மற்றும் ஆசிரியர்கள் பாராட்டினர்.

Program Design: Student Selection Methods

Our RCT was designed to explore the relative effectiveness of multiple aspects of program design. Today I'll focus on talent identification and student support.

On **talent identification** recall that we used four metrics to identify promising students.

Admin	End-of-year 6th-grade math tests
Booklet	Engagement with sample of course test
Quiz	Assessed mastery of booklet (and problem solving skills) after 1 month
Grit	Assessment of perseverance via survey and puzzle

We used eight weighting schemes, randomized across schools.

20%: booklet + quiz + admin

20%: quiz + admin

10%: booklet + quiz

10%: booklet + admin

10%: booklet

10%: admin

10%: quiz

10%: grit

Program Design: Student Selection

We can use the randomization directly and compare the progress made by students selected by each method.

Students selected by the *Admin + Booklet* method score highest on the average engagement and learning measures.

	(1) Successful Completion	(2) AoPS Index	(3) Course Engagement	(4) Alcumus Passing	(5) Challenge Solved	Num. students	Num. schools
Admin+Booklet+Quiz	0.211	0.624	0.576	0.422	0.331	495	178
Admin+Booklet	0.256	0.652	0.585	0.454	0.372	224	79
Admin+Quiz	0.177	0.557	0.508	0.364	0.280	556	197
Booklet+Quiz	0.206	0.591	0.532	0.392	0.322	269	78
Booklet	0.283	0.620	0.571	0.450	0.358	183	78
Quiz	0.227	0.634	0.578	0.436	0.345	200	76
Grit	0.235	0.589	0.519	0.431	0.304	245	74
Admin	0.115	0.502	0.442	0.324	0.227	318	109

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Most other methods perform substantially (and significantly) better than relying purely on *Admin* scores.

Program Design: Student Selection

We can estimate the selection weights that would have been optimal by regressing *Successful Completion* on the measures observed at the time of selection.

- ***Booklet* engagement is the strongest predictor of course performance.**
- This bolsters confidence in the plan of using performance in one course to select students for future courses.
- The regression using a continuous performance index suggests putting weight on several factors.

	Successful Completion	AoPS Index
Admin (*z*)	0.010	0.053***
	(0.016)	(0.015)
Booklet (*z*)	0.069***	0.089***
	(0.011)	(0.010)
Quiz (*z*)	0.015	0.026**
	(0.012)	(0.011)
Grit (*z*)	0.015	0.016*
	(0.010)	(0.009)
Teachers' Top	0.003	0.027
	(0.023)	(0.020)
Mean	0.203	0.590

Program Design: Student Support

A second set of cross randomizations explored student support.

Tutoring Past evidence of high tutor impacts, both group and one-on-one. Are tutors still necessary (or more necessary) for high achievers? Build mentorship, community?

Computer Labs Overcome low engagement with tablets? Facilitate collaboration?

Incentives Reduce risks of tablet misuse, low completion rates?

Program Design: Tutoring

We recruited 54 enthusiastic tutors from top universities. We conducted extensive training and monitored many tutoring sessions.

Students were randomized at the school level into one of three subtreatments.

T1.	50%	No tutoring
T2.	37.5%	Group tutoring Weekly meetings with Tamil-speaking tutors (1hr, 10–15 students)
T3.	12.5%	One on one tutoring Weekly 15 minute meetings

Program Design: Tutoring

The tutoring experiment yields another striking finding: **tutoring support is not necessary to achieve the success we're seeing.**

The result is actually *much* stronger than this:

- *Successful Completion* rates are *28.5%* for students without tutors!
- Differences are highly significant.
- Why we are finding something so different from other settings is a puzzle. High-ability students? Design of AoPS? Reinforcement of low progress? Passivity?

Subtreatment	Mean *Successful Completion*	Regression Estimate
Group Tutoring	0.105	-0.178*** (0.023)
Individual Tutoring	0.174	-0.107*** (0.036)
No Tutoring	0.285	—

Broader Learning

We know from the Alcumus quizzes that many students learned material on 36 topics, often after a great deal of effort.

Does the AoPS course also more broadly improve treatment students' problem solving skills?

We administered a challenging exam that had one easy warmup problem followed by 19 challenging problems that could in principle be solved with knowledge of Tamil Nadu's grade 7-8 curriculum.

Unfortunately, our test was much more challenging than we intended. The mean score was just 11% (just 7% if one drops the warmup question.) This leads to a high standard deviation-to-mean ratio, diminishing our ability to detect moderate percentage increases in the number of challenging problems students solve.

Broader Learning

Preventing cheating is a challenge. We built many cheating-resistant features into our exam and sent proctors to administer it.

Test conditions are also often far from ideal for the students.

Broader Learning

Students in the treatment group scored a little higher.

Significance depends on how one treats the cheaters (about 13% cheated).

- In the full sample the 5% increase in the number of problems solved is not significant.
- Throwing out the scores of the cheaters the 9% increase is significant.
- Gains are not as large as we hoped, but the treatment was just a one-semester course.

	All Students		
	# Students	Mean	Regression
Treatment	1,545	2.28	0.13
			(0.10)
Control	842	2.17	—

	Non-Cheaters		
	# Students	Mean	Regression
Treatment	1,342	2.29	0.20**
			(0.09)
Control	747	2.11	—

Side Effects: Digital Addiction

A small pilot had convinced us that we needed to give students tablets.

The architecture of the AoPS courses (and the design of our program) makes it hard to lock down tablets.

- *PreAlgebra 1* is accessed via a browser.
- AoPS videos are hosted on YouTube.
- WhatsApp had a central role: we use it to contact students and their parents; tutors use it to meet with the students; students were put in WhatsApp groups to build community.

Malamud and Pop-Eleches (2011) report that a program that helped low-income Romanian high school students get internet-connected computers lowered grades. Students spent a lot of time gaming.

Concerns could be greater today with mobile tablets and short-form videos.

Side Effects: Digital Addiction

Our RCT provides an unusual opportunity to look for student distraction harm.

We get student-level data on tablet use from returned tablets.

- The average tablet was used to watch 2.5 hours/day of YouTube!
- Texting and talking was another 40 minutes/day.
- Some good news: gaming and social media app use was just 10 minutes/day.

App Type	Most-Used App	Mean	SD
Video Players	YouTube	2.47	2.27
Communication	WhatsApp Messenger	0.55	0.43
Tools	Google Play services	0.28	0.31
Browser	Google Chrome	0.28	0.25
Phone	Phone by Google	0.17	0.21
Games	Google Play Games	0.13	0.27
Productivity	Google Drive	0.12	0.16
Photography	Gallery	0.10	0.14
Travel & Local	Google Maps	0.07	0.12
Music & Audio	YouTube Music	0.06	0.12
Education	Tamil Nadu 8th Guide	0.03	0.12
Social	Instagram	0.03	0.16

Side Effects: Digital Addiction

Students took 7th grade end-of-year exams in Math, Science, English, and Tamil about two months into our program.

This is not long enough for them to have yet learned much math, but could reveal adverse side effects if students watched YouTube videos instead of studying.

We find no significant effects in regressions of end-of-year scores on treatment assignment (and demographic and baseline variables).

	(1) Math	(2) Science	(3) English	(4) Tamil
Treatment	-0.32	-0.31	-0.93	-0.02
	(0.68)	(0.72)	(0.70)	(0.57)
Control Mean	84.8	86.3	85.6	89.9
Control SD	11.8	12.6	12.3	10.9

Side Effects: Digital Addiction

We can also look in the cross-section at whether students who spent more time on YouTube and other time-wasting apps had lower 7th grade exam scores.

Causal effects and selection effects would both be expected to work in the same direction: spending time on YouTube instead of studying is harmful; and less serious students would be expected to spend more time on YouTube.

Regression coefficients should overestimate the magnitude of negative causal effects of bad apps and the positive causal effects of good apps.

- We estimate precise zero effects of time spent on YouTube.
- Time spent gaming is negatively related to test scores. The aggregate impact would be small given that the average students spent 8 minutes/day gaming.
- Time spent in the browser is positively associated with test scores. This is probably mostly selection.

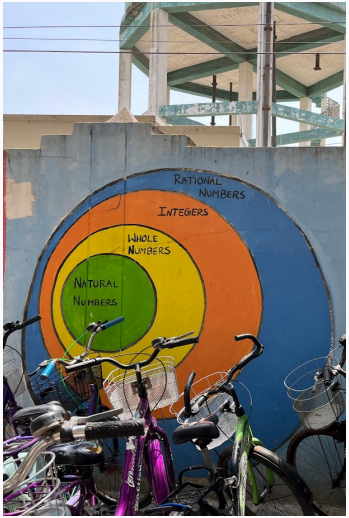
Side Effects: Digital Addiction

	7th-grade scores					
	Math	Science	English	Tamil	*Successful Completion*	Challenging Exam
Video Players	0.15	0.11	0.27	0.18	-0.01	-0.02
	(0.20)	(0.21)	(0.20)	(0.14)	(0.01)	(0.03)
Communication	1.15	-2.84***	-0.77	0.84	-0.03	-0.04
	(0.89)	(0.95)	(0.94)	(0.70)	(0.04)	(0.13)
Voice	-3.56*	-2.55	-2.35	-4.23***	-0.04	-0.44
	(1.88)	(1.79)	(2.12)	(1.27)	(0.07)	(0.27)
Games	-1.82	-2.90**	-2.55**	-2.62***	-0.03	0.09
	(1.15)	(1.21)	(1.17)	(0.99)	(0.06)	(0.19)
Social Media	2.54*	-3.67*	1.51	-1.08	0.03	-0.24
	(1.45)	(2.08)	(1.48)	(2.24)	(0.06)	(0.19)
Browser	3.69***	5.01***	4.92***	3.65***	0.50***	1.11***
	(1.42)	(1.58)	(1.59)	(1.22)	(0.05)	(0.26)
Education	2.39	7.05***	8.91***	3.45	0.15	0.91
	(2.34)	(2.52)	(2.77)	(2.16)	(0.10)	(0.72)
R^2	0.187	0.147	0.162	0.201	0.111	0.101
Control SD	11.8	12.6	12.3	10.9	–	1.7

Long Term Plans

We've recently launched the next phase of our project.

- Select 600 students using AoPS course performance, scores on the challenging exam, variables available at time of initial selection, and randomizations.
- Provide selected students with multiple years of additional courses.
- Assessment focus will shift to progress on pathway to college STEM.
- Randomizations are again designed to allow us to comment on talent identification procedures and the incremental value of program components.



Long Term Plans

Several aspects of the current results are encouraging for scaling up and the long run.

- Adopting the best selection and tutoring procedures should make it possible to substantially boost *Successful Completion* rates.
- The fact that tutoring seems unnecessary will make the program much easier to implement at scale.
- The effectiveness of the booklet in identifying students who will do better in a course suggests that performance in *Prealgebra 1* will also be effective in identifying students who will engage with future courses.
- The lack of observed adverse effects is comforting. (We will still be more aggressive in taking away tablets and have improved our ability to monitor other uses.)

Conclusion

India has a striking missing talent problem. Middle school may be a good place to start addressing it.

- Our procedure was feasible at scale and over 20% thrived in a class designed for English speakers with stronger backgrounds.
- Other designs, e.g. selecting just on admin scores, would not work so well.
- Engagement with a trial portion of a program helps to identify well-matched students.
- Sometimes not having a tutor can be better than having one. Why?
- Tablet misuse seems manageable.
- Will we also narrow the STEM gender gap?

More Learning: Heterogeneity

Many disadvantaged students successfully complete the program. But the usual socioeconomic gaps are mostly still there.

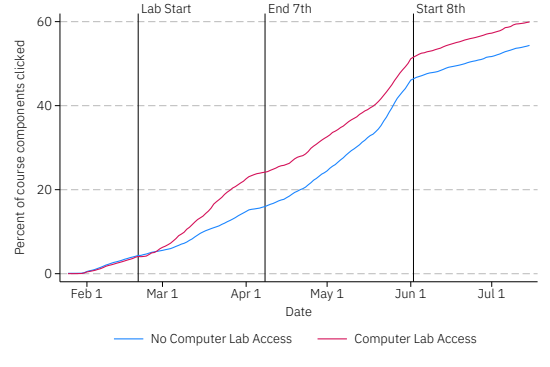
The gender gap is the exception!

	Successful Completion		*Successful Completion*
Female	0.218	Father's Education Level	
Male	0.172	5th Grade and below	0.192
		8th Grade	0.144
Scheduled Caste/Tribe	0.148**	10th Grade	0.173
Not Scheduled Caste/Tribe	0.220	12th Grade and above	0.283
		Father's Employment Type	
Non-English Medium School	0.182*	Daily Wage	0.181
English Medium School	0.230	Private	0.252
		Government	0.318

The gender finding does reverse on the Challenging Exam.

More Design: Working Together In School Computer Labs

A design variant that let students work together after school almost doubled progress in the two months before final exams/summer vacation interrupted.



The early advantage faded over the summer and eventual *Successful Completion* differences are not statistically significant.

More Design: Incentives

We also cross-randomized incentive messaging threatening to take away tablets if students were not making sufficient progress.

We didn't actually take away any tablets until late in the program: it seemed too difficult to do so during the summer vacation.

Subtreatment	Mean *Successful Completion*	Regression Estimate
Enforced Incentives	0.188	0.031
		(0.026)
Unenforced Incentives	0.240	0.052*
		(0.030)
No Incentives	0.185	—

The messaging may have helped a little. In a scale up we would recommend such messaging and taking away tablets.