Impact of Use of Technology on Student Learning Outcomes - Evidence from a Large-scale Experiment in India *

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Abstract

Improvement in quality of school education in developing countries require solutions that are easy to implement and scale-up. Research on use of technologies targeted to improve learning outcomes has so far not addressed issues of implementation and scalability. Most of these technologies require low student-to-computer ratio and large scale retraining of teachers. Our paper is the first to evaluate an intervention design aimed at dealing with these concerns. We conduct a large scale randomized field experiment in 1823 rural government schools in India that uses technology aided teaching to replace one-third of traditional classroom teaching. With student-to-computer ratios comparable to those found in developing countries and minimal teacher training requirements, we get positive impact on student learning outcomes.

Keywords: Information and Communication Technology, Education, Field Experiment, Government Policy

1 Introduction

Recent trends in primary education have seen near universal enrollment rates across the globe.[1] However, these trends have also been marred by insignificant improvements in learning outcomes.[2] Many policy initiatives have been undertaken to improve learning outcomes such as

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[1]Global primary school net enrollment ratio is estimated to have reached 93% in 2015 with highest absolute increase over last 15 years reported from sub-Saharan Africa and South and West Asia (UNESCO, 2015)

[2]Surveys conducted in many developing countries report poor reading and arithmetic skills among children in primary schools. UNESCO (2015) reports several such studies from Africa and Latin America with a low quality of education in schools. In India, 25% of children enrolled in grade 8 could not read at grade 2 level, and 55% could not do simple tasks of division (ASER, 2017)

improving pupil-teacher ratios, training teachers, and providing additional physical infrastructure to schools (UNESCO, 2015). Of these, reliance on technology - both inside and outside the classroom - has been extremely high.[3] However, available evidence on the impact of such technologies has been inconclusive.[4] In addition, technology interventions to improve learning outcomes face issues of implementation and scaling up. Most technology interventions require a student-to-computer ratio much lower than what is currently available in many developing countries.[5] Also, most of these interventions require a change in pedagogy and classroom practices which need large-scale retraining of teachers, impeding the implementation of the intervention.[6] Research has so far not addressed the issues of implementation and scalability of such technologies. Ours is one of the first papers to evaluate an intervention design that deals with these concerns. In this paper, we present evidence from a large scale randomized control trial that uses a novel technology intervention that is highly implementable and scalable.[7] The student-to-computer ratio of our intervention is comparable to that of developing countries and requires minimum changes in pedagogy and classroom practices. Where most studies have not found any impact of large-scale interventions, specially in case of in-school programs implemented by government policies, we are one of the first few papers to find significant positive results of a large-scale in-school experiment.

We conduct a large scale experiment in 1000 randomly selected schools across 18 districts in the State of Karnataka, India. The design identifies a set of 823 schools for comparison with randomization done at the subdistrict level. The intervention began in November, 2014 and continued in the academic year 2015-16.[8] The intervention uses technology assisted teaching to replace one-third of in-school instructional time for English grammar, Math, and Science and is targeted at students from grades 5 to 10 in rural public schools. It combines computers and broadband connectivity with more conventional satellite technology to deliver classes taught by expert teachers at a central location using multimedia teaching aids. These lectures cover the standard syllabus prescribed for all schools in the state by the State Department of Education.

[3]Several multilateral agencies have been aggressively advocating use of ICT in school eduction (World Education Forum, 2015; UNESCO, 2016; World Bank, 2016; Asian Development Bank, 2010).

[4]A review of the literature by Cuban and Kirkpatrick (1998) of research conducted in three decades before 1998 concludes that the evidence on the benefits of computers in education is inconclusive. After nearly two decades, a more recent review by Bulman and Fairlie (2016) reaches a similar conclusion.

[5]Morgan and Ritter (2002); Banerjee et al. (2007); Barrow et al. (2009); Campuzano et al. (2009); Suhr et al. (2010); Carrillo et al. (2011)

[6]Some study designs that require change in pedagogy are Rouse and Krueger (2004); Barrera-Osorio and Linden (2009); Borman et al. (2009); Barrow et al. (2009); Rockoff (2015) while others like Banerjee et al. (2007); Linden (2008); Lai et al. (2013); Mo et al. (2014) require change in classroom practices

[7]As a comparison, the "Mahiti Sindhu" program of the State Government of Karnataka had a target of providing computers to 1000 schools during the project period of 2001 to 2006. The Phases I and II of ICT@schools Project covered 480 and 1571 schools respectively. Phase III of ICT@schools Project covers 4396 secondary schools and high schools and includes schools covered under the "Mahiti Sindhu" Project (DSERT, n.d.)

[8]The school year in Karnataka begins in the month of June and the lectures end in the month of February. Year-end exams are conducted in the month of March. During April and May, schools are closed for vacation.

The intervention requires one computer per school, which for the schools in the State translates to a student-to-computer ratio of 135:1, and is similar to what is observed in most developing countries. While the intervention uses multimedia tools for teaching, the pedagogical adjustments and training requirements for the school teachers are kept at a minimum. This, along with a high student to computer ratio makes the program unique and easy to scale-up.

We evaluate this intervention by conducting tests in a sub-sample of 105 intervention and 98 comparison schools.[9] The sub-sample was selected using a randomization process similar to that followed for selection of the larger sample of 1000 intervention and 823 comparison schools. A pre-test and a post-test were conducted respectively at the beginning and the end of academic year 2015-16 for students in grades 5 to 10. Separate tests were conducted for English grammar, Math and Science based on the curriculum as prescribed by the state authority for all grades. At the end of the year test scores show an improvement between 0.1σ and 0.4σ across different grade-subject combinations. The impact has higher levels of significance for grades 7 to 10. The coefficients of impact are higher in English grammar ranging from 0.2σ to 0.4σ but lower in Math ranging from 0.1σ to 0.2σ. In Science, the impact of the intervention ranges between 0.2σ to 0.3σ. The results remain robust even after adjusting for attrition using Heckman Selection model.

Our intervention is unique in four important ways. First, we analyze an in-school intervention in a developing country in comparison to out-of-school interventions evaluated by most previous studies (Malamud & Pop-Eleches, 2011; Fairlie & Robinson, 2013; Banerjee et al., 2007; Borman et al., 2009; Lai et al., 2013).[10] In-school interventions have the advantage of benefiting all students that attend schools in contrast to out-of-school programs that may be difficult for students to attend after school, specially those from socio-economically disadvantaged sections. Unlike out-of-school programs, in-school programs do not require additional time and effort from the teachers and volunteers (Mo et al., 2014). Most studies of in-school interventions have shown non-significant impact on learning outcomes (Leuven et al., 2007; Barrera-Osorio & Linden, 2009; Belo et al., 2013; Cristia et al., 2014).[11] Our paper is the first to find significant positive impact of a large scale in-school program of using technology to

[9] In an earlier version of this paper we conducted an interim evaluation of the intervention based on SSLC (a state-wide examination mandatory for students completing ten years of schooling to obtain the Secondary School Leaving Certificate.) scores. However, in this paper we evaluate the intervention using pre and post-tests conducted under the project. Evaluating the intervention based on the pre and posts tests is better because (a)it helps us look at the same cohort instead of the different cohorts as in the case of the SSLC data and (ii) impact on all grades from 5 to 10 can be evaluated using the test scores instead of only grade 10 in the SSLC data.

[10] We classify an intervention as an in-school intervention if it is conducted during school hours and replaces at least part of conventional instruction time.

[11] For a more detailed but not exhaustive classification of papers that evaluate impact of use of technology on learning outcomes, please refer Annexure B. The papers are taken from the most recent review of literature by Bulman and Fairlie (2016)

improve learning outcomes with high student-to-computer ratio.

Many intervention designs, for example Banerjee et al. (2007) in India or Carrillo et al. (2011) in Ecuador, that seem easily scalable require a student-to-computer usage ratio of 2:1 or less and an absolute student-to-computer ratio of 13:1.[12,13,14] Given that a third of the countries in Asia and two-third of the countries in Africa have an absolute student-to-computer ratio more than 50 (WSIS, 2014), these numbers can be difficult to implement.[15] We evaluate a program that requires one computer per school, which approximately translates to a student-to-computer ratio of 135:1 for Karnataka and is comparable to those found in many developing countries.[16] This is done by transmitting multimedia content directly to classrooms using satellite communication technology, a laptop and a projector. Figure (2) gives a schematic diagram of the intervention design. Students view the transmitted lectures on a large screen placed in one of the classrooms. A typical intervention class as seen in figure (3) comprises of about 40 to 50 students. At the end of each lecture students can call expert teachers appointed by the program to clarify their doubts about the topic taught. The interactive feature of the intervention is also another improvement over the past large-scale government programs.

Many in-school interventions require teacher training for better use of technology in class. Evaluations of interventions done by Rouse and Krueger (2004), Borman et al. (2009), Barrow et al. (2009), and Rockoff (2015) require teacher training for changes in pedagogy. For developing countries like India, interventions that require retraining of teachers and changes in pedagogy can be costly and difficult to scale up.[17] In addition, programs that require teachers to change pedagogy and classroom practices when implemented at larger scale have given non-significant results (Angrist & Lavy, 2002; Barrera-Osorio & Linden, 2009; Cristia et al., 2014). Unlike previous studies the teacher training requirement in our experiment is kept at a

[12]"Student-to-computer usage ratio" is the number of students that use a computer during one session of the experiment. Whereas "absolute student-to-computer ratio" is the total number of students to the total number of computers used during the entire duration of the experiment. For us the relevant statistic is "absolute student to computer ratio".

[13]Unfortunately most studies do not report the absolute student-to-computer ratio required for the intervention. But since many of these studies (for example by Morgan and Ritter (2002); Barrow et al. (2009); Campuzano et al. (2009); Suhr et al. (2010)) use very low student-to-computer usage ratio, it would be safe to assume a fairly low absolute student-to-computer ratio as well.

[14]Our estimates of absolute student-to-computer ratio are based on the numbers given in Banerjee et al. (2007) and Carrillo et al. (2011)

[15]India, for example, has an absolute student-to-computer ratio of 89 (WSIS, 2014). In Academic Year (AY) 2014-15 a mere 26.42% of schools had a computer (U-DISE, 2016a). In AY 2015-16 this number increased to 27.31% (U-DISE, 2016a)- an indicator of the pace at which the program for introducing computers in schools is progressing in the country.

[16]For example the Lerner:Computer ratio is 89 for India, 98 for Srilanka, 128 for Philippines, 136 for Indonesia, 71 for South Africa, 117 for Ghana, 174 for Morocco (WSIS, 2014)

[17]India has 8.5 million teachers. Karnataka alone has more than 400,000 teachers (U-DISE, 2016a). The average in-service training given to teachers in Karnataka in AY 2013-14 was 2.16 days - an indicator of the capacity of providing in-service training in the State. *(Source: District Information System for School Education (DISE) data)*

minimum, thus making it easily scalable. The intervention that we study eliminates the need for retraining teachers by centralizing content creation and its delivery.

No technology based intervention can succeed at the school level without acceptance and support from the teachers. Teachers are more likely to accept the interventions that cause a minimum disruption in their classroom practices. Literature on technology adoption in schools state that technologies that reinforce or do not disrupt teacher's position, like interactive white-boards, presentation programs such as PowerPoint, are accepted much faster than others like mobile based learning applications where the teacher's role is reduced (Reedy, 2008). Also technologies that allow teachers to control the progress of the curriculum and evaluate learning outcomes of students are more easily adopted than others (Selwyn, 2016). Most in-school interventions like Shapley et al. (2009); Carrillo et al. (2011); Campuzano et al. (2009); Morgan and Ritter (2002); Barrow et al. (2009) and out-of-school interventions such as Banerjee et al. (2007); Linden (2008); Lai et al. (2013); Mo et al. (2014) disrupt the central dominant position of the teachers in the teaching process by not allowing them control over progress of the students. Unlike previous work, our intervention does not require students to interact with a computer, either individually or in groups. The tele-education lectures retain the instructional mode of teaching but with an additional component of multi-media usage. By keeping these basic classroom practices unchanged, we retain the central role of the teacher in the teaching-learning process, and thus have a higher probability of acceptance at the school level.

Our technology design also facilitates real-time monitoring of the systems at schools to ensure effective telecast of the programs. Thus, we overcome major challenges of implementation like non usage of facilities due to teacher intertia, non reporting, theft and pilferage, as observed in earlier government interventions like EDUSAT and Mahiti Sindhu. Technology also allows us to monitor maintenance issues at the school level, allowing for prompt remedial action.

Rest of the paper is organized as follows. Section 2 gives the context in which the intervention was carried out and details of the intervention design. The data used for the evaluation is described in section 3. Estimation, results and robustness checks are discussed in section 4. Section 5 concludes.

2 Intervention Design

The intervention that we analyze in this paper was conducted in Karnataka, one of the relatively better performing states in India (figure 1). The state's per capita income in the FY 2015-16 was about 14% higher than the national average (RBI, 2017). Karnataka has consistently performed better than the national average on most Human Development Indicators (Karnataka Government, 2005). However, the quality of education in the state is just about equal to that of the national average. As seen in Table (1) percentage of students in grade 8 who could read grade 2 text, read words and sentences or do division is lower than the national averages (ASER, 2017).[18]

Table 1: Maximum Learning Levels of Children in Class VIII

	Reading Levels					
	Not even letter	Letter	Word	Std I text	Std II text (+)	Total
India	2.0	5.4	6.5	13.0	73.0	100
Karnataka	2.1	3.3	8.6	16.0	70.0	100
	Arithmetic					
	Recognize Numbers			Can Subtract	Can Divide	Total
	None	1-9	10-99			
India	1.2	6.1	26.2	23.3	43.2	100
Karnataka	1.1	2.0	25.4	29.4	42.2	100

Source - ASER (2016). The survey covers both government as well as private schools in rural India

Computer / technology aided educational interventions in a country like India face multiple implementation issues. One of these challenges is the availability of basic infrastructure like computers and connectivity in schools. Only 39.53% schools in Karnataka and 27.31% schools in India had computers for educational purpose (U-DISE, 2016a).[19] 45,648 schools in Karnataka and 1.1 million schools in India did not have computers in AY 2015-16.[20] As regards to connectivity, among schools in Karnataka that have a secondary section or above (Grades 8 to 12; 24.02% of total schools), only 30.73% had an Internet connection in AY 2015-16. Similarly, in India out of 16.57% schools which have secondary section or above, 40.05% had internet connection in AY 2015-16 (U-DISE, 2016b). Connectivity in schools with only primary and upper primary sections is likely to be far lower. Thus, an intervention to improve learning outcomes that requires minimal infrastructure becomes crucial in a developing country like India.

Intervention Design - Satellite and Multimedia Interactive Education (SAMIE)

We analyze SAMIE (Satellite and Multimedia Interactive Education) program, implemented as a Public-Private-Partnership between the Department of Education, Government of Karnataka and the Indian Institute of Management, Bangalore (IIMB) Consortium and funded by the State

[18] Of the total children enrolled in grade 8, 30% of them could not read grade 2 text (national average 27%). The learning levels in arithmetic is closer to national average. Of the total children enrolled in grade 8, 57.8% of them could not do simple division problems (national average 56.8%) (ASER, 2017).

[19] An important point to note while interpreting this number is that, it includes private unaided schools which constitute 23.4% of the total schools in Karnataka and 19.4% in India. These schools usually charge a high fee and are equipped with good infrastructure including computers, connectivity and educational software. If we remove these schools and consider only rural government schools, then the proportion of schools with computers will be far lower.

[20] The pace of computerization of schools has also been slow in India. For the country as a whole, out of 1.12 million schools without computers in AY 2014-15, a mere 1.2% schools received computers in AY 2015-16

Department of Education. The objective of this project was to design an intervention to increase educational achievement levels among students, under conditions similar to those in a developing country i.e. maximum reach with minimal requirements of additional infrastructure and retraining of teachers.

SAMIE used satellite transmission technology (V-SAT communication) and broadband connectivity to deliver content in government schools in rural Karnataka. This ensured state-wide coverage at near zero marginal costs. A central studio in Bengaluru (the State Capital) was used to transmit live lectures that cover State Board syllabus for English grammar, Math and Science for grades 5 to 10. The receiving apparatus at the school level was a laptop connected to a projector and a screen. This laptop was connected to broadband Internet to facilitate monitoring. This was used for sending auto-generated SMS from the laptops in schools to the central server in Bangalore reporting system status and VSAT signal strength. This facilitated real-time monitoring in the schools and ensured proper functioning of the systems.

The program focused on rural government schools whose majority students are from socio-economically disadvantaged sections of the society. Further, we focused on selecting schools in the economically backward regions of the State. We used the classification criteria of the High Power Committtee on Redressal of Regional Imbalances (popularly known as the Nanjundappa Committee) (Nanjundappa, 2002) to pick 18 districts with the lowest development score. The Nanjundappa Committee Report classifies taluks in Karnataka into four broad categories (Relatively Developed, Backward, More backward and Most Backward), using an index based on multiple development measures. From each of the 18 districts selected, four taluks were randomly selected to be part of the study. Two of these taluks in every district were randomly assigned to receive the intervention and the other two were assigned to the comparison group. In each of these taluks, all government and government-aided schools that satisfied the criteria of having a minimum level of facilities required to run a tele-education class were included in the intervention and comparison groups. These criteria were - (a) closed classroom in good condition with adequate security for the equipment, (b) working electricity connection (c) a minimum of 20 students in each class (d) either availability of existing internet connectivity or feasibility of providing connectivity by the ISP. Our experiment covered on an average 15% of schools in the intervention taluks and 13% schools in comparison taluks. Ultimately, 1000 schools were included in the intervention group and 823 in comparison group. Comparison of these two groups of schools on various observables such as student enrollment and demographics, physical infrastructure, and characteristics of teachers is given in Table (A1).

The program employed well-trained teachers and research teams to deliver lectures from the central studio in Bangalore with access to a broad range of knowledge resources and expertise in content delivery software. A conceptual diagram of the project is given in figure (2). Teams of teachers researched a topic and developed a lesson plan which was passed on to content developers who developed multimedia content to accompany the lesson.[21] A detailed time-table of the topics to be covered in each lecture was circulated to the schools at the beginning of the academic year. The classes were held during the regular school hours. The medium of instruction of the classes was Kannada, which is the mother tongue of most children in Karnataka. For each subject and grade, the program allocated two classes per week, each of 40 minute duration. Each lecture was followed by an interaction time of 10 minutes where students asked questions to subject experts. Each system at school also included a mobile phone to facilitate video chat between students in schools and the subject experts. This was done over broadband connection. However, in the year under study, only at 561 out of 1000 schools had broad band connection. In cases where broadband connection was not available, basic mobile connectivity was used to make voice calls.

Rarely do rural areas have a single school with both primary and secondary grades. Students from neighboring primary (grades 1 to 4) and upper primary (grades 5 to 8) schools usually go to a single secondary school (grades 9 and 10) in the taluk. A random selection that allocates an upper primary school in a taluk to intervention group and a secondary school in the same taluk to comparison group or visa versa would create high possibilities for spill-overs. To avoid such spillovers, the unit of randomization of our experiment was a taluk instead of a school as is the normal practice in such studies.[22] Migration across taluks is possible but relatively low. Technology used for the experiment was selected on the basis of its techno-economic feasibility given the conditions in the remote areas where the schools were located. However, from the experiment design perspective, another incidental advantage was control of spillovers. Unlike distribution of education content using CDs or over public internet websites, it is not easy for schools in the neighborhood to access content provided over a VSAT link in a school.

The school year in Karnataka begins in the month of June and the lectures end in the month of March with April and May being vacation months. The SAMIE intervention started in the month of November 2014 and continued until February 2015. In the subsequent AY 2015-16, the intervention ran for the entire length of the academic year i.e from June, 2015 till February, 2016.

[21] Most intervention designs that encourage students to directly interact with computers to facilitate learning rely on a constructivist theory of learning wherein the students are free to explore the subject matter on their own. Our intervention, relies on cognitive learning theory wherein it is believed that cognition takes place in a child through multiple channels i.e. audio, visual, olfactory, etc. For permanent and effective learning it is recommended to use as many of these channels as possible (Mayer, 2002).

[22] Most experimental studies, such as Banerjee et al. (2007); Linden (2008); Lai et al. (2013); Mo et al. (2014) to name a few, randomize either at school level or at class level.

3 Data

We evaluate the intervention by conducting pre and post tests at the beginning and end of AY 2015-16 respectively in 105 intervention and 98 comparison schools. The schools were selected from the population of intervention and comparison schools on the basis of stratified random sampling i.e. proportion of schools from each taluk in this smaller sample was kept the same as that in the original sample of 1000 intervention and 823 comparison schools. All grades from 5 to 10 in the selected 203 schools were administered tests in English grammar, Math and Science at the beginning and end of AY 2015-16. The tests covered standard syllabus prescribed by the State Department of Education for all schools in the state. The pre-test was based on the syllabus taught in the previous grade while the post-test covered the syllabus taught in the AY 2015-16 i.e. current year. Each of the tests comprised of 20 multiple choice questions and a descriptive question. The tests were designed on the basis of Andersen-Bloom Taxonomy of learning objectives (Anderson et al., 2001).[23] The tests were conducted by teachers in respective schools under the guidance of trained program personnel. Test schedule was provided to all schools in advance. All students present in the school on the day of the test were administered the tests. Details of the number of students who took the tests is given in table (A6). As can be seen from the table, attrition is substantial as many students could take only one of the two tests. Section 4 discusses the attrition problem in greater detail.

We take school level data on enrollment, academic and physical infrastructure for our intervention and comparison schools for two years i.e. AY 2013-14 and 2014-15 from the Karnataka State Department of Education database. We also use the data on teachers in each school for AY 2014-15 from District Information System for Education (DISE) database maintained by National University of Educational Planning and Administration (NEUPA). We use these school characteristics as controls in our estimation. Data on SSLC scores of grade 10 students from these schools is obtained from Karnataka Secondary Education Examination Board (KSEEB).[24]

Table (A3) compares the 203 schools where pre-test was conducted. We see that schools from this intervention and comparison groups are statistically similar on most observables. The proportion of students from the ST community is more in the intervention group thus placing the intervention group at some a disadvantage in terms of academic achievements.[25] However, when one considers the total of ST and OBC students (who are better off in terms of academic

[23]In comparison to SSLC exams, the pre and post test based on Andersen-Bloom Taxonomy is better suited to evaluate the impact of the program as it is more in line with the learning objectives of the experiment.

[24]SSLC (Secondary School Leaving Certificate) exam is a state-wide examination conducted by the KSEEB in April and October every year. This exam is mandatory for students completing ten years of schooling to obtain the Secondary School Leaving Certificate. Students taking the exam for the first time usually take it in the month of April (i.e. end of academic year).

[25]SSLC data over last decade shows that students from ST community have been scoring less than general category students by 15-17%

achievement), the difference between the two groups is not statistically significant. Table (A4) compares the baseline test scores for intervention and comparison groups in the three subjects.[26] While the students from intervention schools have scored less than those in comparison schools, the difference is not statistically significant in majority cases. An important requirement for our estimation is that past trends of outcome variable should be parallel between intervention and comparison groups. To check this we compare SSLC performance of grade 10 students from these schools over last 10 years. Table (A5) shows that the assumption of parallel past trend in performance is satisfied.

4 Estimation and Results

We use a two period difference-in-difference method to estimate the impact of the intervention. As there is considerable amount of attrition in our data, we check for robustness of these estimates using a two-step Heckman selection model. We first estimate the Intention to Treat (ITT) impact of the intervention using the following two-period difference-in-difference equation -

$$Y_{ijt} = \alpha + \beta_1 D_j + \beta_2 test_t + \beta_3 D_j * test_t + \beta_4 X_{jt} + \beta_5 .dist_j + \epsilon_{ijt} \tag{1}$$

where, Y_{ijt} denotes marks obtained by student i in school j in test t. i.e. pre-test or post-test as the case may be. D_j indicates treatment status of the school j and $test_t$ is the test indicator which could either be pre or post test. The parameter of interest here is β_3. X_{jt} are school characteristics for school j in time t.[27] As mentioned earlier, we use school data for two years i.e AY 2013-14 and AY 2014-15 which we assign to baseline and endline respectively. We estimate this equation separately for each grade-subject combination. In all our estimations we add district fixed effects, $dist_j$ and cluster errors at the taluk level (Glennerster & Takavarasha, 2013). We also standardize all scores around the mean of the comparison group at the base line for each subject-grade combination. The coefficients thus have an "effect size" interpretation and can be directly compared with results from other similar studies.

Table (A9) gives estimated values of coefficient β_3 in equation (1). The first six columns of table (A9) estimates equation (1) for all students who appeared either for pre-test or post-test or both without taking into account the impact of attrition. Columns (1) to (3) in these tables give estimates for English, Math and Science respectively without school level controls. In columns (4) to (6) we add school level controls. As can be seen from the tables, the impact of the intervention on learning outcomes as measured by these tests is positive in all cases. The

[26] Unless other-wise stated, we use standardized test scores around the pre-test mean and standard deviation of respective comparison groups, for all analysis.

[27] We use subscript t to denote both tests and time. Thus $t = 0$ indicates both pre-test and base year.

impact ranges from 0.1σ in case of grade 8 Math score to 0.38σ for grade 7 Math score. The estimates are significant in many cases and for others, the standard errors are not too large.

As mentioned earlier, there were many students who appeared for pre-test but were absent during the post tests. Similarly, there were some who appeared in the post tests but were absent in the pre-test. We, drop students who did not appear for the pre-test from further analysis as we do not know how the intervention affected them. Columns (7) to (9) in Table (A9) gives comparison of only those students who appeared for pre-test. As can be seen from the table, the coefficients are still positive in all cases and remain significant in most cases.

About 60% of students took both pre and post tests. We exploit the panel characteristics of the data for this subset of students by estimating the following first difference equation.

$$\Delta y_{ij} = \alpha + \beta_1.D_j + \beta_2.\Delta x_j + \beta_3.dist_j + \epsilon_{ij} \tag{2}$$

where Δy_{ij} is the difference in the pre-test and post-test score of student i in school j. D_j is the intervention indicator for school j. Δx_j are first-difference values of school level controls mentioned above. We take the difference in these variables between AY 2013-14 and AY 2014-15. In all our estimation we add district fixed effects and cluster errors at taluk level . We estimate equation (2) separately for each subject-grade combination. The coefficient β_1 gives the difference-in-difference estimate of the impact of the project. The estimates given in columns (1) to (6) of table (A10) corroborate the conclusion that the intervention has had a positive impact on all subject-grade combinations and impact is significant in many cases.

Robustness Check

In this experiment attrition arises on two accounts. Firstly, a student may drop-out from the school. Due to the large size and geographical spread of the experiment, it was not possible to track attrition of students due to this factor. The intervention might have reduced the drop out rate on an average across schools by improving learning outcomes and making the learning experience more enjoyable by use of multi -media. This would only have a downward bias on the impact estimates. Another, source of attrition is the inability of students to appear either for pre or post tests despite undergoing the intervention. If we only compare the number of students appearing for pre and post tests, the attrition rate appears to be in the range of 9% of students appearing for pre-test in intervention and comparison groups across various subject-grade combinations. However, when we remove students who have appeared for only one of the two tests, we get high attrition rates ranging from 26.3% to 46.7% in intervention group and from 28.8% to 43.8% in comparison group (table A6).[28] In table (A7) we compare the pre-test

[28]Post-test could not be conducted in 8 out of 203 schools in which pre-test was conducted. Out of these 8 schools, 4 schools each were in the intervention and comparison groups.

scores of absentees from intervention and comparison groups. However, table (A8) shows that as a result of attrition of this group, the difference in pre-test scores of those who remained in the experiment were no longer non-significant in many cases. We, therefore, do a robustness check, by adjusting the impact estimates for selection bias using the 2-step Heckman model (Wooldridge, 2010). We model the first step probit equation as -

$$P(attend_{ijSt} = 1|w_{ijt}) = G(\alpha + \beta.D_j + \sum\nolimits_{s \neq S} \gamma_s.marks_{s(t-1)} + \sum_{t}^{t-2} \psi_t.x_{jt} + u_{ijt}) \quad (3)$$

where $attend_{ijSt}$ is an indicator variable that takes value $attend_{ijSt} = 1$ if the student i from school j attends a test in time t in subject S. Since we use only data on students who attend the pre-test i.e. $attend_{ijSt-1} = 1$, the equation estimates the probability of such a student attending the post-test. This selection process is modeled using w_{ijt} which includes observed values of variables for students who attend the pre-test i.e. pre-test scores in other subjects $s \neq S$ ($marks_{s(t-1)}$) along with current and lagged values of school characteristics (x_{jt}) such as total enrollment, proportion of enrollment by caste and gender, and number of teachers. $G(.)$ is the *cdf* of a normal distribution. In the second step of Heckman Selection model, the Inverse Mills Ratio (IMR) arrived at using the results of equation (3) is added as control variable to the outcome equation (2) -

$$\Delta y_{ij} = \alpha + \beta_1.D_j + \beta_2.\Delta x_j + \beta_3.dist_j + +\beta_4.IMR + \epsilon_{ij} \quad (4)$$

We then estimate equation (4) using data only of those who have appeared for both, pre-test as well as post-test. Columns (7) to (9) of Table (A10) gives attrition adjusted estimates of the impact of intervention. As can be seen from the table the impact is robust to any possible bias on account of attrition and we continue to get positive estimates in the range of 0.1σ to 0.4σ.

The attrition numbers and the negative sign of the coefficients in Table (A7) indicates that interventions such as these encourage low performing students in the intervention groups to appear for tests. This could either be a result of the additional attention provided by the experiment staff or on account of increase in confidence of the students due to the intervention program. As a result, in presence of attrition the ITT estimates of impact of intervention are likely to have a downward bias if the impact of intervention is positive (Angrist et al., 2006; Glennerster & Takavarasha, 2013). If this is the case, the impact estimates should be higher for sample of students who appeared for both, pre-test as well as post-test which is what we see when we compare the ITT estimates in table (A9) with the attrition adjusted estimates in table (A10).

5 Discussion and Conclusion

Even after taking into consideration attrition, the intervention seems to have increased the learning levels of the students by 0.1σ to 0.4σ across various grade-subject combinations. These results are better than most of the in-school program evaluations such as Angrist and Lavy (2002); Barrera-Osorio and Linden (2009); Cristia et al. (2014) who get non-significant results. In fact the gains in some cases are better than the most in-school (Campuzano et al., 2009; Morgan & Ritter, 2002; Barrow et al., 2009) as well as out-of-school (Borman et al., 2009; Lai et al., 2013) small scale experiments. To the best of our knowledge, only Banerjee et al. (2007); Linden (2008), and Muralidharan et al. (2016) have got higher impact but with much lower student-to-computer ratios.

Considering the fact that most estimates of impact of our intervention are between 0.2σ to 0.3σ, the cost of achieving one standard deviation increase per student per year works out to USD 6.9 which is comparable to other interventions such as Banerjee et al. (2007) and Linden (2008). For the purpose of computing above costs, a five year lifespan is considered for the project. The project did not use any voluntary workers and all project staff was paid at prevailing market rates. The Private sector project partner provided all the hardware, multi-media content, rent for up-link studio facility, and trained and experienced teachers for delivering lectures at the central studio. The V-SAT bandwidth was made available by the government at zero cost.

The importance of this intervention lies in the fact that it is the first to achieve a positive impact on English grammar, Math and Science scores at such a high student-computer ratio of 135:1, thereby making the intervention design replicable in most developing country settings. Equally important, is the fact that the increase in learning outcome has been achieved with minimal requirement for retraining of teachers. In fact, anecdotal evidence during field visits suggests that many teachers use the tele-education classes to update their knowledge and teaching techniques. In one particular case where the government had introduced a new chapter on trigonometry in grade 9 Math syllabus, many teachers informed us that the tele-education classes were useful to them in revising their own concepts on the topic. Further, by keeping basic classroom practices unchanged, our intervention design retains the central role of the teacher in teaching-learning process. The tele-education lecture does not require students to interact with a computer and retains the instructional mode of teaching with additional use of multi-media to facilitate cognition. This, along with minimal teacher re-training requirements is also likely to increase acceptance for the program among teachers at the school level.

We recognize that our design suffers from some drawbacks. One of the expected advantages of technology is the possibility to create constructivist learning environments in the classrooms, where students, either individually or in groups explore knowledge domains of their choice and learn at their own pace, with teacher playing the role of a facilitator (Schunk, 1996; Hung, 2001). However, this not only requires large number of computers with schools, but also new pedagogies, classroom practices and a massive retraining exercise for the teachers. An important aspect of these new pedagogies is that they displace the teachers from their the central role in the teaching-learning process (Haugsbakk & Nordkvelle, 2007; Biesta, 2013, 2015). Another major drawback of this design is that it cannot offer additional attention to those slow learners who are not able to keep pace with proceedings in the standard classroom (Banerjee et al., 2007; Muralidharan et al., 2016). As such, the study is likely to suffer from a similar disadvantage pointed out by Glewwe et al. (2009), where additional inputs provided tends to benefit those students who are already better performing. Technology creates the possibility to reaching to each child in the manner, form and time that is most suitable for him or her. Our design is not able to accomplish this. While, there can be real gains in attempting such projects, the hardware and training requirements would mean that such projects would take a long time to implement and stabilize.

However, we believe that with the slow pace at which information technology is being introduced in countries like India, creating hardware, software and human capabilities to implement such constructivist and personalized education programs is still in a distant future. When it comes to educating the children, can governments and societies afford to wait for so long? We feel that in the meanwhile, there are some low hanging fruits in the education sector that can be exploited immediately with the use of already existing resources and capabilities. Our intervention design is an attempt in this direction.

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Table A1: Comparison of Full Sample

	Comparison Mean	Intervention Mean	t-statistic	p-value
Panel A	School Characteristics[a]			
Total Enrolment	197.90	189.60	1.47	0.14
Total Classrooms	6.26	6.70	−2.55	0.01
Working Teachers	8.51	8.53	−0.11	0.91
Pupil-Teacher-Ratio	28.24	27.25	1.32	0.19
Pupil-Classroom-Ratio	41.72	37.95	4.07	0.00
Infrastructure Score[c]	7.42	7.56	−2.69	0.01
Panel B	Teachers[b]			
Number of Teachers(sec)	8.75	8.75	0.06	0.95
Number of Female Teachers(sec)	2.88	3.09	−1.66	0.10
Academic Qualification Score	13.06	13.05	0.09	0.93
Professional Qualification Score	1.78	1.76	0.73	0.47
Proportion of Female Teachers	0.31	0.34	−2.01	0.04
Proportion of OBC Teachers	0.50	0.51	−0.45	0.65
Proportion of SC Teachers	0.17	0.16	0.28	0.78
Proportion of ST Teachers	0.06	0.07	−2.45	0.01
Teacher Experience (Years)	17.60	22.29	−2.82	0.00
	Student Demographics[a]			
Proportion of Girl Students	0.48	0.48	−0.56	0.58
Proportion of SC Students	0.23	0.24	−1.18	0.24
Proportion of ST Students	0.11	0.14	−3.33	0.00
Proportion of OBC Students	0.53	0.50	2.54	0.01
Proportion of OBC+ST Students	0.65	0.64	0.97	0.33

[a] Source: Government of Karnataka, Department of Education - AY 2013-14

[b] Source: DISE - AY 2014-15

[c] Infrastructure score for each school is computed on the basis of availability of various facilities in the school including those mentioned in the Right to Education Act, 2009. These include facilities such as electricity, playground, library, boundary-wall, special ramps and toilet for differently abled students, etc. One point is awarded for each of the facilities. Thus a high score indicates better infrastructure.

Table A2: Parallel Trend in Grade 10 Results[a] for Full Sample

	Dependent variable:			
	Total	English	Math	Science
	(1)	(2)	(3)	(4)
Intervention:Year2007	5.475	1.676	0.841	0.883
	(6.656)	(2.283)	(1.373)	(1.447)
Intervention:Year2008	1.126	−0.791	−0.191	0.243
	(7.855)	(2.282)	(1.562)	(1.671)
Intervention:Year2009	−0.473	0.597	−0.928	−0.355
	(8.657)	(2.531)	(1.870)	(1.974)
Intervention:Year2010	−2.677	−1.664	−1.749	−0.315
	(8.779)	(2.677)	(1.892)	(1.832)
Intervention:Year2011	1.258	−0.751	−1.456	0.449
	(8.590)	(2.170)	(2.038)	(1.779)
Intervention:Year2012	11.839	0.056	0.992	2.172
	(9.283)	(2.309)	(2.043)	(1.870)
Intervention:Year2013	5.477	0.078	−0.730	0.983
	(9.138)	(2.403)	(2.096)	(1.657)
Intervention:Year2014	5.984	−0.628	−0.042	0.911
	(8.769)	(2.790)	(1.843)	(1.604)
Intervention:Year2015	5.865	0.024	−0.205	1.451
	(9.229)	(2.875)	(1.892)	(1.895)
Intervention:Year2016	−1.931	−1.279	−0.919	0.286
	(10.086)	(2.873)	(1.993)	(1.961)
Note:				*p<0.1; **p<0.05; ***p<0.01

[a] Scores of students in grade 10 in SSLC exam. 728 schools out of 1000 schools in intervention group and 634 schools out of 823 in Comparison group have classes up to grade 10. Here we consider only those schools that have a secondary section for all 10 years which is 658 and 585 for intervention and comparison groups respectively. Each column is a regression of SSLC marks in given subject on Year and Intervention dummy. Coefficients reported are for the interaction term. Non-significance of these coefficients indicates parallel trend.

Table A3: Comparison of 203 Schools Sub-Sample

	Comparison Mean	Intervention Mean	t-statistic	p-value
Panel A	School Characteristics[a]			
Total Enrolment	191.32	184.76	0.51	0.61
Total Classrooms	6.46	6.48	−0.04	0.97
Working Teachers	8.67	8.59	0.29	0.77
Pupil-Teacher-Ratio	27.04	25.72	0.92	0.36
Pupil-Classroom-Ratio	40.84	37.26	1.38	0.17
Infrastructure Score[c]	7.65	7.43	1.51	0.13
Panel B	Teachers[b]			
Number of Teachers	8.88	8.64	0.64	0.52
Number of Female Teachers	3.54	3.21	0.95	0.34
Academic Qualification Score	12.80	12.99	−0.55	0.58
Professional Qualification Score	1.71	1.76	−0.89	0.38
Proportion of Female Teachers	0.39	0.36	1.06	0.29
Proportion of OBC Teachers	0.51	0.48	0.85	0.40
Proportion of SC Teachers	0.17	0.18	−0.29	0.77
Proportion of ST Teachers	0.06	0.08	−1.62	0.11
Teacher Experience (Years)	16.32	22.82	−1.84	0.07
	Student Demographics[a]			
Proportion of Girl Students	0.47	0.47	−0.04	0.97
Proportion of SC Students	0.24	0.24	0.12	0.91
Proportion of ST Students	0.10	0.15	−2.68	0.01
Proportion of OBC Students	0.54	0.47	1.88	0.06
Proportion of OBC+ST Students	0.64	0.62	0.58	0.56

[a] Source: Government of Karnataka, Department of Education - AY 2013-14

[b] Source: DISE - AY 2014-15

[c] Infrastructure score for each school is computed on the basis of availability of various facilities in the school including those mentioned in the Right to Education Act, 2009. These include facilities such as electricity, playground, library, boundary-wall, special ramps and toilet for differently abled students, etc. One point is awarded for each of the facilities. Thus a high score indicates better infrastructure.

Table A4: Difference in Scores of Intervention and Comparison Groups in Pre-test

	5th	6th	7th	8th	9th	10th
English	−0.395	−0.383	−0.300	−0.094	−0.101	−0.152
	(0.286)	(0.256)	(0.270)	(0.131)	(0.148)	(0.108)
Math	−0.342	−0.333	−0.382*	−0.044	−0.224*	−0.074
	(0.264)	(0.238)	(0.229)	(0.154)	(0.134)	(0.149)
Science	−0.220	−0.338	−0.245	−0.104	−0.067	−0.117
	(0.245)	(0.224)	(0.212)	(0.141)	(0.113)	(0.136)
Note:				*p<0.1; **p<0.05; ***p<0.01		

All figures are coefficients of the intervention indicator from regressing the pre-test score for each grade-subject combination over intervention and district indicators. All scores are standardized around mean and standard deviation of pre-test scores of respective comparison groups. Figures in brackets are standard errors and are clustered at taluk level

Table A5: Parallel Trend in Grade 10 Results[a]for Sub-Sample of 203 Schools

	Dependent variable:			
	Total	English	Math	Science
	(1)	(2)	(3)	(4)
Intervention:Year2007	−5.187	4.249	0.269	−0.239
	(9.412)	(3.922)	(2.328)	(2.316)
Intervention:Year2008	−7.968	−1.566	0.911	−1.985
	(9.879)	(5.218)	(2.013)	(2.537)
Intervention:Year2009	−10.449	1.977	−0.537	−1.324
	(11.800)	(3.639)	(2.333)	(3.136)
Intervention:Year2010	−12.959	0.641	−1.748	−1.364
	(13.372)	(5.218)	(2.763)	(2.876)
Intervention:Year2011	−1.983	−1.925	−1.601	0.559
	(12.288)	(4.746)	(2.777)	(2.749)
Intervention:Year2012	7.889	7.588	0.322	1.049
	(12.525)	(5.479)	(2.847)	(2.861)
Intervention:Year2013	5.104	9.930*	−1.127	1.718
	(12.984)	(5.590)	(2.847)	(2.471)
Intervention:Year2014	5.994	4.365	0.181	0.876
	(12.681)	(3.541)	(2.738)	(3.001)
Intervention:Year2015	14.857	5.942	2.243	3.465
	(13.897)	(3.862)	(2.941)	(2.969)
Intervention:Year2016	−5.917	3.426	−1.691	0.894
	(14.183)	(3.701)	(3.082)	(2.884)
Note:	*p<0.1; **p<0.05; ***p<0.01			

[a] Scores of students in grade 10 in SSLC exam. 77 schools out of 105 schools in Intervention group and 69 schools out of 98 in Comparison group have classes up to grade 10. Here we consider only those schools that have a secondary section for all 10 years which is 67 and 66 for intervention and comparison groups respectively. Each column is a regression of SSLC marks in given subject on Year and Intervention dummy. Coefficients reported are for the interaction term. Non-significance of these coefficients indicates parallel trend.

Table A6: Number of Students Appearing for Pre and Post Tests

Grade	Control			Treatment		
	Pre-test (1)	Post-test (2)	Common (3)	Pre-test (4)	Post-test (5)	Common (6)
			English			
5	737 (29.58%)	745	519	734 (46.73%)	585	391
6	935 (35.29%)	892	605	878 (36.90%)	855	554
7	1014 (34.22%)	886	669	970 (34.54%)	927	635
8	2902 (36.91%)	2738	1831	3339 (28.33%)	3040	2393
9	3727 (38.53%)	3354	2291	4014 (34.03%)	3596	2648
10	3578 (43.82%)	3070	2010	3900 (30.10%)	3583	2726
Total	12893 (38.55%)	11685	7923	13835 (32.44%)	12586	9347
			Math			
5	738 (30.76%)	728	511	756 (41.14%)	674	445
6	939 (37.49%)	850	587	910 (38.35%)	856	561
7	987 (30.29%)	924	688	987 (36.58%)	915	626
8	2949 (33.57%)	2748	1959	3293 (27.42%)	3043	2390
9	3667 (36.02%)	3454	2346	4126 (30.61%)	3594	2863
10	3564 (43.10%)	3006	2028	3934 (26.79%)	3708	2880
Total	12844 (36.79%)	11710	8119	14006 (30.28%)	12790	9765
			Science			
5	732 (28.83%)	733	521	750 (42.53%)	668	431
6	931 (34.91%)	853	606	886 (41.87%)	858	515
7	1010 (32.08%)	892	686	1028 (38.72%)	906	630
8	2931 (34.05%)	2744	1933	3389 (27.47%)	3048	2458
9	3747 (34.83%)	3432	2442	4106 (30.13%)	3600	2869
10	3549 (40.83%)	2966	2100	3925 (26.32%)	3718	2892
Total	12900 (35.75%)	11620	8288	14084 (30.45%)	12798	9795

Figures in brackets give percent attrition. Columns (3) and (6) gives number of students who appeared for both pre and post tests. The numbers in post-test include some students who appeared for post-test but not for pre-test.

Table A7: Comparison of Pre-test Scores of Absentees between Intervention and Comparison Groups

	Dependent variable:		
	English	Math	Science
	(1)	(2)	(3)
5th	-1.688	-0.742	-4.662^{**}
	(2.818)	(2.460)	(2.186)
6th	-0.880	-0.899	-2.587^{*}
	(1.203)	(1.203)	(1.511)
7th	-0.855	-2.610^{***}	-2.231^{**}
	(0.955)	(0.777)	(1.110)
8th	-0.537	0.373	-0.198
	(0.412)	(0.754)	(0.646)
9th	-0.165	-0.512	-0.113
	(0.646)	(0.645)	(0.575)
10th	-0.492	-0.405	-0.318
	(0.308)	(0.558)	(0.662)
Note:	*p<0.1; **p<0.05; ***p<0.01		

All coefficients are values of Intervention dummy in regression of pre-test scores on intervention status and district indicators for respective grade-subject combination. The dependent variables are the absolute marks scored in pre-test (out of total 30 marks). Data used is of those students who attended only the pre-test. Figures in brackets are standard errors and are clustered at taluk level.

Table A8: Comparison of Pre-test scores of Panel between Intervention and Comparison Groups

	Dependent variable:		
	English	Math	Science
	(1)	(2)	(3)
5th	-4.681^{***}	-3.219^{***}	-2.526^{**}
	(1.226)	(0.870)	(1.113)
6th	-3.007^{**}	-1.864^{*}	-1.903^{*}
	(1.281)	(1.000)	(1.119)
7th	-2.512^{**}	-2.169^{**}	-0.862
	(1.141)	(0.920)	(1.184)
8th	-0.495	-0.240	-0.791
	(0.436)	(0.348)	(0.514)
9th	-0.468	-0.774^{**}	-0.289
	(0.552)	(0.346)	(0.425)
10th	-0.711^{**}	-0.496	-0.952^{**}
	(0.279)	(0.399)	(0.394)
Note:	*p<0.1; **p<0.05; ***p<0.01		

All coefficients are values of Intervention dummy in regression of pre-test scores on intervention status and district indicators for respective grade-subject combination. The dependent variables are the absolute marks scored in pre-test (out of total 30 marks). Data used is of only those students who attended both pre-test and post-test. Figures in brackets are standard errors and are clustered at taluk level.

Table A9: Pooled Regression

	All Students						All Students appearing for Pre-test		
	Dependent variable:								
	English	Math	Science	English	Math	Science	English	Math	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5th Grade	0.351	0.292	0.339	0.330	0.222	0.290	0.329	0.179	0.287
	(0.298)	(0.246)	(0.230)	(0.296)	(0.255)	(0.232)	(0.312)	(0.255)	(0.239)
6th Grade	0.191	0.205	0.391*	0.163	0.160	0.362	0.110	0.110	0.329
	(0.229)	(0.201)	(0.211)	(0.240)	(0.209)	(0.220)	(0.245)	(0.219)	(0.220)
7th Grade	0.340	0.434**	0.363**	0.283	0.385*	0.304	0.277	0.327	0.285
	(0.246)	(0.219)	(0.182)	(0.242)	(0.197)	(0.187)	(0.248)	(0.218)	(0.194)
8th Grade	0.216	0.069	0.181*	0.229	0.087	0.190*	0.220	0.071	0.186*
	(0.134)	(0.137)	(0.105)	(0.142)	(0.143)	(0.107)	(0.145)	(0.135)	(0.107)
9th Grade	0.205	0.316**	0.212**	0.206	0.326**	0.219**	0.177	0.301**	0.220**
	(0.133)	(0.129)	(0.106)	(0.133)	(0.132)	(0.106)	(0.129)	(0.118)	(0.107)
10th Grade	0.318**	0.177	0.242***	0.338**	0.187	0.265***	0.317**	0.158	0.253***
	(0.125)	(0.134)	(0.087)	(0.134)	(0.134)	(0.086)	(0.148)	(0.131)	(0.083)
School Control	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

All coefficients are values of interaction between Intervention and test indicators (β_3) in the estimation equation (1) for respective grade-subject combination. For columns (1) to (6), data includes all students who appeared either for pre-test or post-test or both. For columns (7) to (9) data includes all students who appeared for pre-test but may or may not have appeared for post-test. All regressions include district dummies. Figures in brackets are standard errors and are clustered at taluk level.

Table A10: Panel Data - First Diff

	Dependent variable:								
	English	Math	Science	English	Math	Science	English	Math	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5th Grade	0.598**	0.315	0.303*	0.595**	0.242	0.267	0.486	0.199	0.228
	(0.256)	(0.205)	(0.176)	(0.273)	(0.222)	(0.185)	(0.301)	(0.228)	(0.170)
6th Grade	0.276	0.275*	0.439*	0.391	0.337	0.346*	0.377	0.304	0.266
	(0.241)	(0.162)	(0.229)	(0.245)	(0.218)	(0.207)	(0.240)	(0.227)	(0.204)
7th Grade	0.618***	0.481***	0.192	0.559**	0.359***	−0.013	0.479**	0.279*	−0.056
	(0.213)	(0.164)	(0.208)	(0.236)	(0.135)	(0.182)	(0.230)	(0.168)	(0.182)
8th Grade	0.233*	0.090	0.234**	0.152	0.071	0.228***	0.227*	0.156*	0.330***
	(0.120)	(0.090)	(0.093)	(0.120)	(0.089)	(0.084)	(0.128)	(0.086)	(0.094)
9th Grade	0.182	0.268**	0.239**	0.151	0.262**	0.208**	0.215	0.257**	0.198*
	(0.139)	(0.114)	(0.111)	(0.138)	(0.106)	(0.101)	(0.146)	(0.115)	(0.108)
10th Grade	0.383***	0.155	0.337***	0.352***	0.151	0.341***	0.431***	0.106	0.300***
	(0.112)	(0.123)	(0.069)	(0.118)	(0.118)	(0.069)	(0.125)	(0.140)	(0.099)
School Control	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
IMR	No	No	No	No	No	No	Yes	Yes	Yes
Note:									*p<0.1; **p<0.05; ***p<0.01

All coefficients in columns (1) to (6) are values of Intervention dummy in the estimation equation (2) for respective grade-subject combination. Columns (7) to (9) estimate equation (4). Data includes only those students who appeared for both pre-test as well as post-test. All regressions include district dummies. Figures in brackets are standard errors and are clustered at taluk level.

Figure 1: Karnataka State in India

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Figure 2: Intervention Design

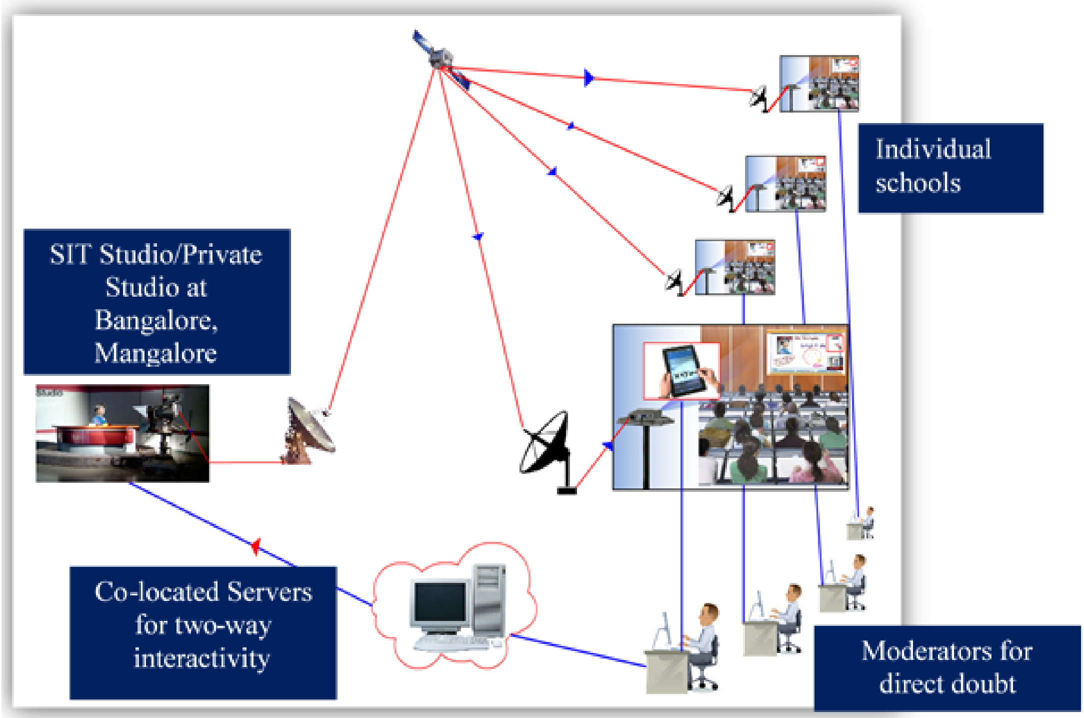

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Figure 3: SAMIE Class

Figure 4: Districts selected for intervention

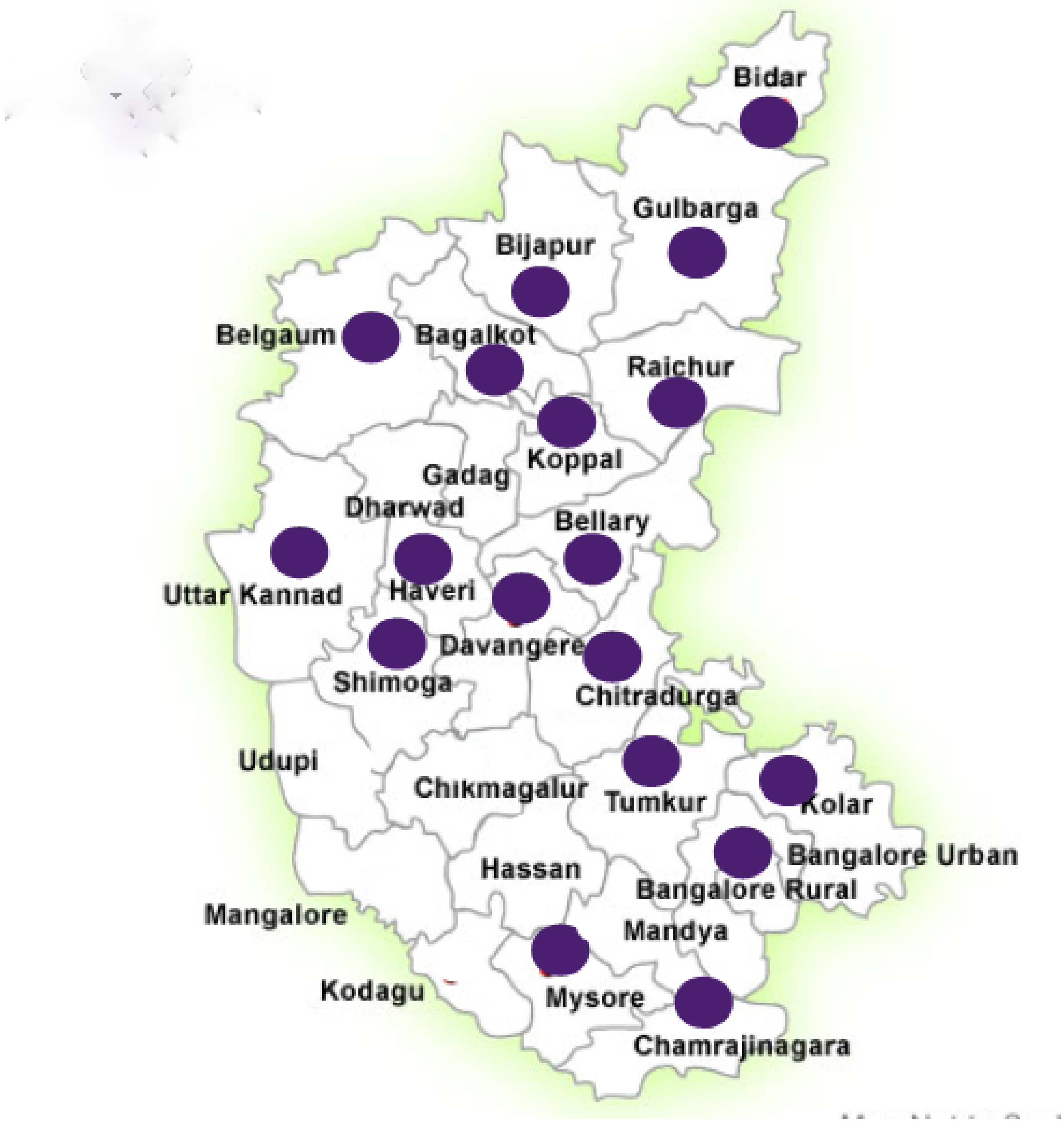

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Figure 5: Difference between Intervention and Comparison groups in Pre-test and Post-test - English

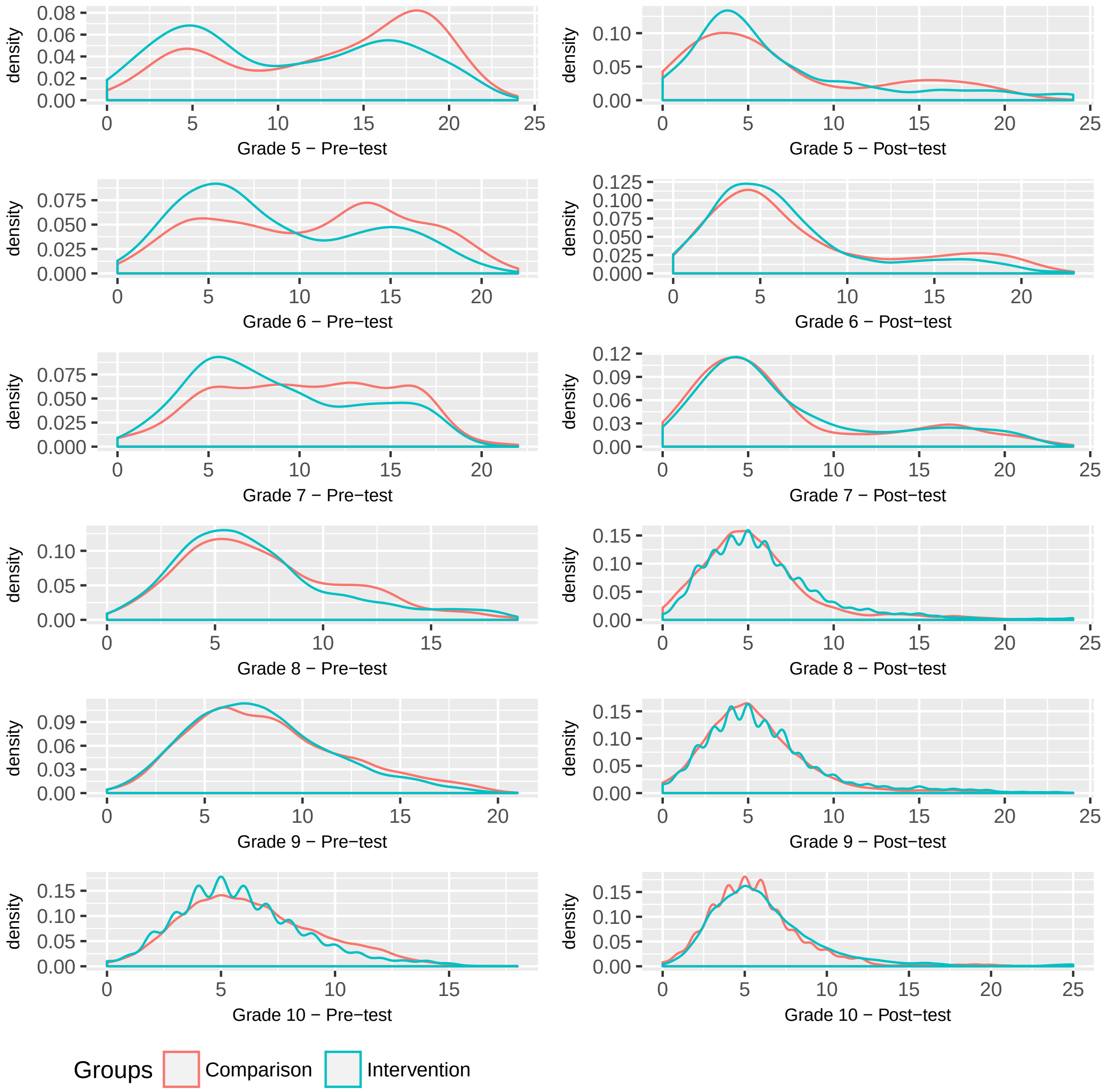


Figure 6: Difference between Intervention and Comparison groups in Pre-test and Post-test - Math

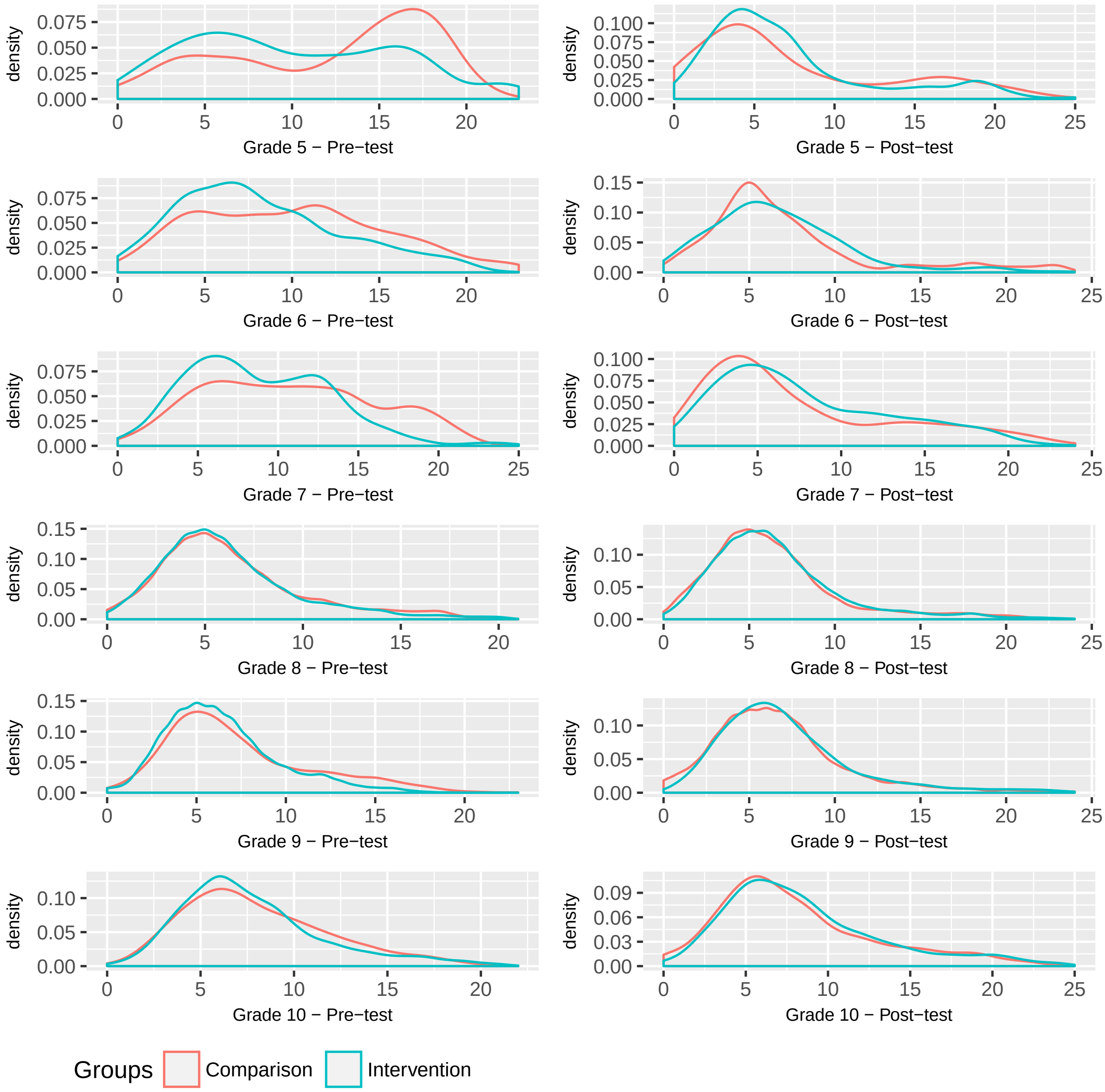
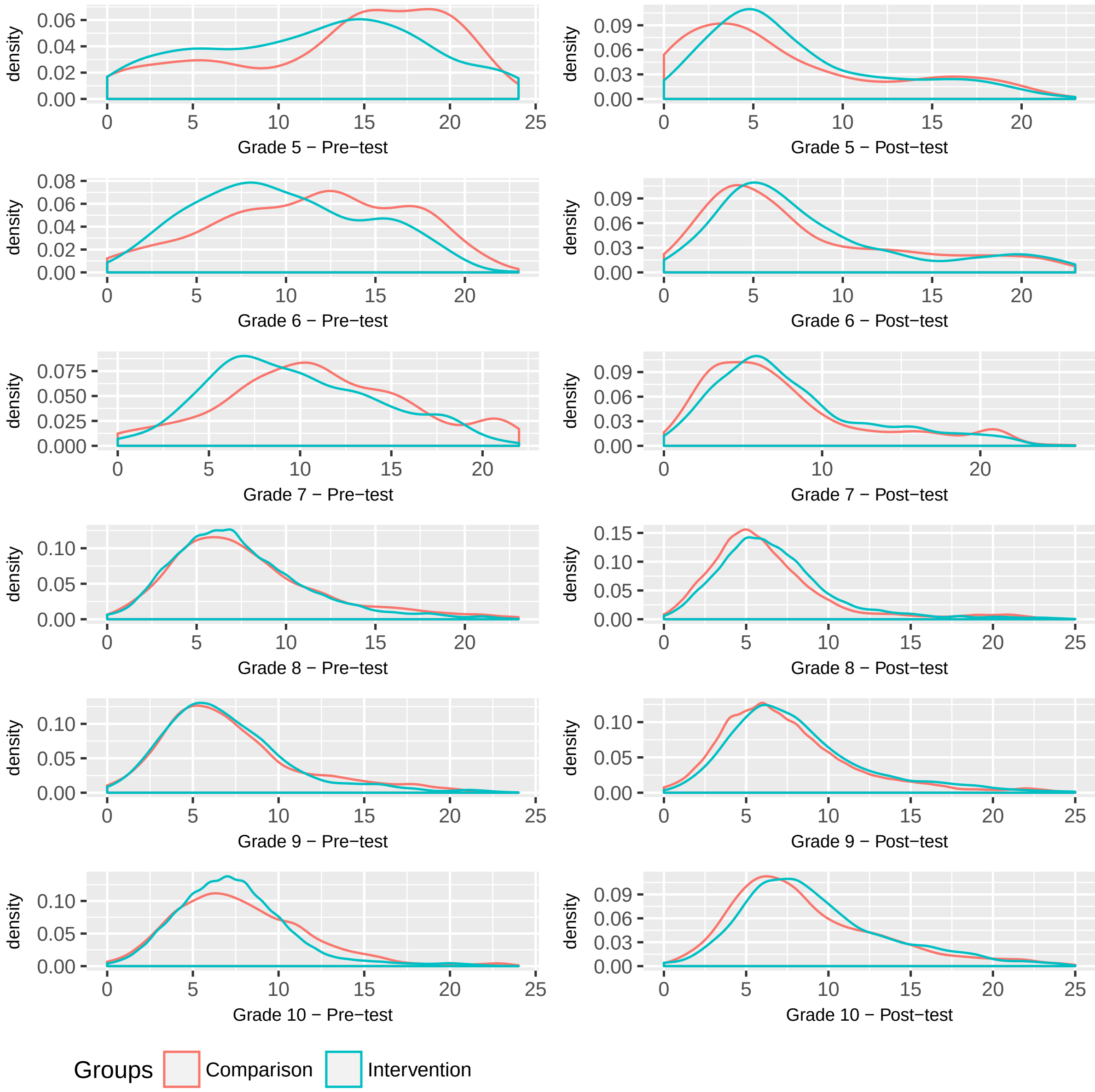


Figure 7: Difference between Intervention and Comparison groups in Pre-test and Post-test - Science



Annexure - B

Table B1: In-School Programs - No Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Angrist and Lavy (2002)	Israel	10	Yes	No	122	Math (NA); Language (NA)
(2)	Goolsbee and Guryan (2006)	USA	NA (Internet subsidies)	No	No	8000(+)	Math (NA); Language (NA); Science (NA)
(3)	Leuven et al. (2007)	Netherlands	5	Yes	No	328	Math (NA); Language (NA)
(4)	Barrera-Osorio and Linden (2009)	Colombia	NA	Yes	Yes	48 (6386)	Math (NA); Language (NA)
(5)	Belo et al. (2013)	Portugal	NA (broadband)	No	No	537	Math (-); Language (-)
(6)	Cristia et al. (2014)	Peru	NA	Yes	Yes	649	Academics (NA)

Table B2: In-School Programs - (+) Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Machin et al. (2007)	UK	5	Yes	No	591 LEAs	English (+); Math (NA); Science (+)
(2)	Shapley et al. (2009)	USA	1	Yes	Yes	21	Math (+); Language (+); Science (NA); Social Sciences (NA)
(3)	Carrillo et al. (2011)	Ecuador	13	No	Yes	8 (400)	Math (+); Language (NA)

Table B3: In-School Experiment - No Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Rouse and Krueger (2004)	USA	1	Yes	Yes	4	Language (NA)
(2)	Dynarski et al. (2007)	USA	NA	Yes	Yes	132	Language (NA); Math (NA); Algebra (NA)
(3)	Linden (2008)*	India	1	No	Yes	30	Math - In (-); Out (+)
(4)	Rockoff (2015)	USA	1	Yes	Yes	4	Math (NA)

* Two intervention arms - In-school and Out-of-school

Table B4: In-School Experiment - (+) Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Morgan and Ritter (2002)	USA	1	Yes	Yes	5	Math (+)
(2)	Barrow et al. (2009)	USA	1	Yes	Yes	17	Math (+)
(3)	Campuzano et al. (2009)	USA	NA	Yes	Yes	77	Language (NA); Math (NA); Algebra (+)*
(4)	Suhr et al. (2010)	USA	1	Yes	No	2	Language (+)
(5)	Mo, Zhang, Luo, et al.(2014)	China	2	No	Yes	36	Math (+)

* Interaction between usage and scores not significant

Table B5: Out-of-School - No Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Malamud and Pop-Eleches (2011)	Romania	1	No	No	5650 vouchers	Math (-); Language (-)
(2)	Fairlie and Robinson (2013)*	USA	1	No	No	15	Academics (NA)
(3)	Beuermann et al. (2015)	Peru	1	No	No	14	Academics (NA)

* is an Experiment. Others are evaluation of government programs. In all studies students were allowed to take their computers home.

Table B6: Out-of-School - (+) Impact

	Paper	Country	Stu:Comp	Role of Teacher	Pedagogical Change	Schools	Results
(1)	Banerjee et al. (2007)	India	2	No	Yes	55	Math (+)
(2)	Linden (2008)*	India	1	No	Yes	30	Math - In (-); Out (+)
(3)	Borman et al. (2009)	USA	1	Yes	Yes	8	English - Grade 2 (NA); Grade 7 (+)
(4)	Lai et al. (2013)	China	2	No	Yes	36	Math (+)
(5)	Mo, Zhang, Luo, et al.(2014)	China	2	No	Yes	36	Math (+)
(6)	Lai et al. (2015)	China	2	No	Yes	24	Math (+)
(7)	Lai et al. (2015)	China	2	No	Yes	26	Language (+); Math (+)

* Two intervention arms - In-school and Out-of-school