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Challenges in educational reform: An experiment on active learning in mathematics[☆]

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HIGHLIGHTS

- Experiment designed to affect the ability to reason and argue using mathematics.
- Used structured pedagogical intervention aimed at secondary school students.
- The intervention was implemented with high fidelity and was internally valid.
- The control group learned more than the treatment group.

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ABSTRACT

This paper reports the results of an experiment designed to improve secondary school students' ability to reason and argue using mathematics. A structured pedagogical intervention was created to foster a more active role of students in the classroom. The intervention was implemented with high fidelity and was internally valid. Surprisingly, students in the control group learned significantly more than those who received treatment.

1. Introduction

Improving student learning is high on the list of priorities for policymakers. There is no consensus, however, about what is the most effective policy to achieve this goal. A vast literature in economics (Hanushek et al., 2016) reflects the range of available instruments: school choice, human resources policies, school and classroom management policies and, school resources. However, there is hardly any work (Machin and McNally, 2008) that looks at whether the instructional approach employed has any substantive effect on student learning. Understanding the effect of teaching strategies is important because they underpin all learning in the classroom. This paper reports the main results of a large clustered randomized control trial with secondary school students in Costa Rica designed to improve their ability to think, reason, argue, and communicate using mathematics.[1] These goals are at the core of educational reforms in developed and developing countries.

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[1] A full report of the experiment, the intervention and its results can be found in Berlinski and Busso (2015).

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2. Experiment

Eighty-five public schools participated in our experiment during the school year 2012. On average these schools were representative of the schools in Costa Rica. Schools were assigned to one of five conditions: control (20), active learning (20), active learning plus an interactive whiteboard (15), active learning plus a computer lab (15), and active learning plus one computer per student (15). We assigned schools to their experimental status using a block randomization procedure based on school enrollment. We notified the government and the schools of the lottery results at the beginning of the school year. All schools in the experiment, including those in the control group, were asked to teach Geometry during the second trimester to accommodate training and the deployment of technology.

The teaching of mathematics in the control group is similar to that observed in other secondary schools in low and middle income countries. The class is characterized by lecture—style teaching in which the teacher writes down a definition or procedure on the blackboard using a particular example. Students take notes, ask questions and practice what the teacher explained. The students take a passive role in this process.

In contrast, as a recent study from the European Commission highlights, many countries are "moving away from the traditional teacher-dominated way of learning, active learning approaches encourage pupils to participate in their own learning through discussions, project work, practical exercises and other ways to help them reflect upon and explain their mathematics learning" (Eurydice, 2011: 56). We commissioned a group local experts (with the advice of an international team) the design of pedagogical material to introduce a more modern approach to the teaching of mathematics.

We produced a teacher's manual and a student's workbook which were structured so that it would not demand significant time of study by teachers. The workbook/manual's sections covered all the seventh-grade Geometry curriculum. Each section shared a similar structure, divided into three activities: exploration, formalization, and practice of concepts. The materials incorporated the use of classroom resources to facilitate those activities: pre-specified software applications for those classes where some technology was available and images or paper models in their absence. Additionally, we provided teacher training with a hands-on approach to the new teaching approach and opportunities to validate the class material. The full training session had 40 h, divided into 4 weeks with 10 h each week. A total of 130 teachers participated in the full training program and 115 finished it successfully.

In schools assigned to the one-to-one status, classrooms were equipped with one laptop per student that stayed in the classroom. In schools assigned to the interactive whiteboard status, classrooms were equipped with one interactive whiteboard. Schools assigned to the computer lab status had one laptop for every two students available for at least 2 h a week. Schools either used their existing computer laboratories or in their absence we created mobile laboratories for them. All teachers in classrooms with technology had a laptop and a projector.

3. Data

A key feature of the design of any experiment is a valid, relevant and fair[2] outcome measure. We designed our assessment variable, a measure of geometry knowledge, following standard educational and psychometric procedures (Shechtman et al., 2010). A 32-item test with sound psychometric properties was administered on pen and paper towards the end of the intervention (mid-August to mid-September).

Additionally, at baseline we administered a standardized mathematics achievement test. We collected student and teacher survey data before the intervention started, between late April and early May, and towards the end. During the experiment, we also collected teacher logs and classroom observations. This information was used to assess treatment take-up and changes in teacher's and student's behavior.

The experiment included nearly 18,000 students and 190 teachers in 85 schools. We collected data on all teachers and schools and we randomly selected one classroom per teacher (from an average of three) to collect student's data. Fig. 1 shows pre-treatment sample means of relevant covariates and the *p*-values of t-tests of the differences in these means across treatment groups. Overall these differences are small and not statistically significant.

4. Results

We estimate our results using a regression specification which includes dummy variables for the four treatments and controls for randomization strata and predetermined student, teacher and school characteristics. Standard errors are clustered at the school level.[3]

Use of resources and allocation of time. The usage of resources and changes in the allocation of time show high compliance with the treatment. We use the endline student surveys to create indicators of classroom material and technology use. The results for these outcomes are presented in the top panel of Table 1 where the dependent variable indicates whether students had access and used the materials and technology provided to their class by the intervention. All estimates are positive and large. We cannot reject the null hypothesis that classes in each treatment arm used the materials. In the bottom panel of Table 1, we use classroom observations to show the way time was allocated in the classroom. The observer recorded the duration in minutes of the three main moments of the class: exploration of new concepts, formalization, and practice. As intended, more time was devoted to exploration and formalization and less to practice in the treatment arms.

Student learning. We interpret the changes in the use of resources and allocation of time as an indication that teachers decided to use the materials and equipment offered to them. Unfortunately, this did not translate into learning gains. Table 2 presents the main results of the paper. The dependent variable is the score in the geometry test standardized using the mean and standard deviation of the control group. Students in the treatment arms learned less geometry than those in the control group. In the top panel, the average treatment effect of the active learning treatment alone is −17.1% of a standard deviation. The effect of active learning with one-to-one computers was −35.5% of a standard deviation. All coefficients are statistically significant at standard levels. In the bottom panel of Table 2 we divide the sample equally on teacher experience and student ability. There is a larger relative loss for students with less experienced teachers and for students with higher knowledge of math at baseline.

Behavior. These learning results could be due to either lower effort from students or teachers, or a worsened interaction between the teachers, the students and the subject. In Table 3, we look at measures of those outcomes using endline surveys and classroom

2 This is to say, an outcome that does not bias the measurement in favor of the treatment by emphasizing certain activities and styles that have been used during the intervention.

3 We provided *p*-values unadjusted and adjusted for multiple testing using the Holm's (1979) step-down procedure.