# Pre-Analysis Plan:
# Closing Indonesian Students' Mathematics Gap: The High-Tech High Touch Pilot – Program MENGEJAR[1]


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## Abstract

Most students in low- and middle-income countries lack foundational numeracy skills. Only the privileged few could master higher-order skills. We conduct a randomized evaluation to study whether technology and teacher training can improve foundational and higher-order numeracy skills. We test two treatment arms: an adaptive learning software to address foundational mathematics deficiency and teacher training sessions on pedagogy to improve higher-order mathematics skills. Our study covers 150 public junior secondary schools, involving approximately 330 teachers and 20,000 grade 7 students. The outcome variables are students' foundational and higher-order mathematics skills, non-cognitive skills, and mathematics anxiety. We also examine teachers' motivation, practice, and teaching efficacy. We measure spillovers to non-participating teachers and students in the participating schools.



**Keywords:** computer-adaptive learning, differentiated learning, educational technology, foundational skills, higher-order teaching skills, mathematics

**JEL Codes:** I 21, I 24, I 25

**Study pre-registration: AEA** (AEARCTR-0009640)


## Research Questions

This study examines the impact of high-tech and high-tech/high-touch interventions on learning outcomes. Our interventions have three components:

1. A 10-hour training session on changing teachers' paradigms. The training consists of four parts:
    - Teacher's commitment to improving teaching;
    - Teacher's role in facilitating active learning;
    - Understanding differences in students' learning levels;
    - Understanding the importance of a stimulating environment for learning.
2. An adaptive learning software, *Surala Ninja!,*[7] is provided to teachers and their students. The software is designed to be used during mathematics classes for an average of 80 minutes per week, equivalent to 40% of the total time allocated for mathematics classes in one week. The lessons are held in the school's computer lab during this time. In addition, teachers receive 20 hours of training and continuous support from the Surala implementation team to facilitate the software.
3. A 12-hour training session to teach higher-order thinking skills. It consists of six topics: (i) exploring mathematics around us; (ii) developing mathematical tasks; (iii) understanding students' mathematical thinking; (iv) facilitating discussions in mathematics classrooms; (v)

[7] The *Surala Ninja!* software has been implemented in private schools in Indonesia since 2015. The software is already adapted to the Indonesian national school curriculum and is delivered in Bahasa Indonesia. The Surala team also has a support infrastructure in place. For this study, however, the team modified the teacher training component to suit the motivation and interest of public school teachers

observing characteristics of effective mathematics classrooms; (vi) developing a lesson plan. Approximately one month after the end of the training, facilitators will pay a one-time visit to the participating teachers' classrooms to assess their teaching skills and provide feedback. From the observation, the lowest performing 40% of teachers will be invited to a refresher course to improve their teaching skills further.[8]

The teacher paradigm and higher-order skills training sets underwent a design, iteration, and revision process between October 2021 and May 2022. Two organizations, Mentari Teachers Academy and The SMERU Research Institute, were selected through a competitive process to develop these training sets. From the three components, we implement two treatment arms, detailed as follows:

1. **High-Tech Only** (**HTO**), in which, at maximum, 120 students in the seventh-grade cohort receive access to *Surala Ninja!*, is to be used during the mathematics lesson for one school year for an average of 80 minutes per week. The teachers are provided with the teacher paradigm and Surala training (components 1 and 2 above).
2. **High-Tech High-Touch** (**HTHT**), in which, in addition to the high-tech intervention and the teacher paradigm training, selected mathematics teachers to receive a series of teacher training sessions aimed at improving the teachers' skills to facilitate a more stimulating environment for learning competence of delivering a mathematics learning, which is expected to improve the students' higher-order thinking skills.

***Outcomes.*** We are interested in evaluating how these interventions affect the following outcomes as detailed in Table 1.

Table 1: List of target outcomes

| **Category** | **Target Outcome** | **Measurement Tool** |
|---|---|---|
| Primary Outcome | Students' numeracy skills | Student learning assessments (SLA) in numeracy |
| Intermediate Outcome | Students' literacy skills | Student learning assessments (SLA) in literacy |
| | Students' motivation and interest in learning mathematics | Study habits and ability to use technology as a learning tool |
| | Students' belief in a | Student questionnaires on |

[8] The decision to invite only 40% lowest performing teachers were decided based on budget availability and ensuring cost-effectiveness of the program.

| | | |
|---|---|---|
| | growth-oriented mindset | socioeconomic profile and learning habits |
| | Students' mathematics anxiety, with regards to both learning and testing in mathematics | Student questionnaires on learning habits |
| | Teachers' mathematics knowledge up until grade 7 level | Teachers' math assessment |
| | Teachers' mathematics pedagogy skills | Teachers' mathematical pedagogy assessment and class observation |
| | Teachers' reported effort in teaching mathematics | Teacher interviews and questionnaires |
| | Teachers' belief in a student-oriented learning | Teacher questionnaires |

***Hypotheses***

We have the following hypotheses:

1. First, the computer-adaptive learning (CAL) software will increase students' foundational skills.
2. Complementing CAL with teacher training will improve students' higher-order thinking skills.

Therefore, we expect students in HTHT schools to have better higher-order thinking skills but similar foundational skills than students in HTO schools. In turn, students in these schools would have higher foundational skills than control schools.

## Contributions

Our study contributes to the literature in three ways. First, we implement the interventions in the public school system. They are delivered during school hours and using schools' existing infrastructure. Most CAL interventions are implemented outside the public school system: Muralidharan et al. (2019) work with privately-run after-school tutoring centers in India, while Bellinger (2021) implements a pilot in high-ranking private schools in Vietnam. Recent systematic reviews show no studies in the public school setting (Van Schoors et al., 2021; Major et al., 2021). Whether the technology can be implemented in public schools – with poor teacher competence and incentive systems (World Bank, 2017) and strict financial constraints – remains an open question, despite its essential policy relevance.

Second, we contribute to the literature on improving students' higher-order thinking skills by examining the role of teacher training in pedagogy aimed at improving these skills. Evidence suggests that teacher professional development programs mostly have small effects (Popova et al., 2022). However, the available evidence is mainly limited to training teachers on basic pedagogical approaches or specific subjects. Emerging evidence shows benefits from more innovative pedagogies using problem and inquiry-based learning (Bando et al., 2019), yet evidence on higher-order thinking skills remains rare.

Third, our study contributes to a further understanding the complementarity between teachers and technology. There is a general lack of understanding of the teacher's role in making CAL more effective (Major et al., 2020). Conversely, there is also a lack of CAL interventions in the context where the country already adopts differentiated teaching into the national curriculum. We explicitly build this complementarity into the interventions by (i) increasing the role of technology in teaching *foundational* skills and (ii) increasing the role of teachers in teaching *higher-order* skills.

Given its timeliness, our study can have a large policy impact. With growing evidence of the effectiveness of "teaching at the right level," policymakers in many LMICs have begun considering implementing differentiated teaching. In Indonesia, the Ministry of Education, Culture, Research, and Technology (MoECRT) piloted an implementation of differentiated teaching in 2020 and officially incorporated it into the new national curriculum in 2022 (Heyward, 2022). Our focus on public schools and the ministry's interest in differentiated teaching means that the evidence we produce will provide critical and timely insights into future education reforms in Indonesia. Evidence for successful and cost-effective interventions can provide a blueprint that can potentially be adopted at scale by the Indonesian government.

# Study Design

## District Selection

We implement the interventions in Central Java (the City of Semarang, Kendal Regency, and Tegal Regency) and Jakarta (East Jakarta, West Jakarta, and Central Jakarta). The chosen districts are districts with established partnerships with Tanoto Foundation,[9] one of our partners in this project. We target these districts for two reasons:

1. The established partnership between the districts and Tanoto Foundation simplifies obtaining local government support, a key element for successful implementation (Education Commission, 2020); and
2. The existing partnership allows us access to schools with adequate supporting infrastructure that satisfies the technical requirements stipulated by one of our implementing partners, Surala,[10] which provides the computer adaptive technology software, *Surala Ninja!*.

## Sample Selection

We target the seventh-grade students and their mathematics teachers in the selected public junior high schools in three districts/cities in Central Java: Semarang City, Kendal, Tegal, and Jakarta (East, West, and Central Jakarta). The public junior high schools we target must fulfill the following criteria:

1. The public junior high school must not participate in the *Sekolah Penggerak*[11] Cohort 1 program
2. The public junior high school must not be a partner school of Tanoto Foundation and does not implement Tanoto Foundation's PINTAR program;[12]
3. The schools must also have adequate supporting infrastructure to implement the CAL software (*Surala Ninja!*), which are:
    i. Average internet download speed of at least 50 Mbps

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[9] Tanoto Foundation operates across many provinces and districts in Indonesia. Access https://www.tanotofoundation.org/en/about-us/where-we-operate/ for further information regarding this matter.

[10] Surala is a Japanese-based educational technology company focusing on adaptive learning technology in mathematics. In Indonesia, they operate under the name PT Surala Suluh Karsa. Access https://surala.jp/en/services/surala/ (Japanese parent company) and https://surala.co.id/ (Indonesia-based company) for further information.

[11] *Sekolah Penggerak* is one of the Indonesian Ministry of Education, Culture, Research, and Technology's flagship programs aimed at improving the students' literacy and numeracy learning outcomes holistically by providing trainings and monitored guidance for principals and teachers for selected schools in Indonesia (Ministry of Education, Culture, Research, and Technology, n.d.)

[12] PINTAR Program is the flagship program by Tanoto Foundation aimed at improving Indonesia's basic education quality through improving the school's teaching and learning competence and transforming the school's leadership strategy. Further information: https://www.pintar.tanotofoundation.org/tentang-pintar/

ii. An adequate number of functioning PCs/laptops for, at minimum, 50% of students in one classroom to individually use the device (i.e., no device sharing is necessary for at least half of the students in one classroom).

Our power calculation (described in the next section) requires 150 public junior high schools that fit our eligibility criteria. In each school, we plan to include, at maximum, 120 seventh-grade students (approximately 3-4 classrooms) and, at minimum, 2 mathematics teachers who are responsible for teaching the chosen seventh-grade classrooms. In the case where the schools only have one mathematics teacher for the seventh-grade students (which is often the case in some smaller eligible schools), we will include (in hierarchical order):

- Mathematics teachers responsible for the eighth-grade or ninth-grade students **or**
- Teachers from STEM subjects, like science or ICT teachers, **or**
- School counselors/counseling teachers

Thus, we expect to include at maximum 18,000 seventh-grade students, and minimum 300 seventh-grade (mathematics) teachers in this program. We will also include students with physical and/or intellectual disabilities in the implementation of interventions.

## Power Calculation

Our power calculation for the impact evaluation assumes a statistical test of size 0.05 and a 0.8 power to detect a minimum detectable effect size of at least 0.13 SD for each treatment arm relative to the control group. To conduct the power calculation, we use the results of a mathematics aptitude survey among junior secondary students in Yogyakarta collected in 2019 (Berkhout et al., 2022). Our power calculation yields a sample of about 50 schools for each treatment arm under the assumption of 60 students in each school.

## Treatment Assignment

Schools are assigned to the control/treatment arm using a stratified-random assignment. We stratify all eligible schools based on their district and whether the school average of their national exam (from 2019) was above or below the district median. Schools are randomly assigned to each treatment/control arm from each stratum. Within each school, we chose two teachers that teach seventh-grade mathematics to participate in our high-touch training and intervention. We chose the participating class and students for the high-tech intervention based on the selected teachers. We randomly selected two classrooms from the selected high-tech classrooms for the baseline survey.[13]

## Data Collection

### Baseline Survey

We have conducted a baseline survey of 60 seventh-grade students and 2 mathematics teachers in each school. Regarding schools with less than 60 students[14], we sampled the universe of students. Regarding students with physical and/or intellectual disabilities, we included them in the baseline survey if said student belongs to the randomly chosen classroom for the baseline study. However, we are still determining whether we will include the information we obtained from them in our analysis because we want to see their response in the baseline survey.

### End-line Survey Instruments

For our endline study, we will employ the same instruments that we used in our baseline study, in addition to a classroom observation module. The details of each instrument will be explained in Table 2.

Table 2: Baseline instruments and indicators

| No. | Target respondent group | Instrument | Indicators covered |
|---|---|---|---|
| 1 | Student | Student learning assessment | • Student's foundational numeracy ability and higher-order thinking skills up to the seventh-grade level<br>• Student's literacy ability until the seventh-grade level |
| 2 | | Questionnaires on learning habits, growth mindset[15], and | • Students' (or family of the students') socioeconomic background |

[13] A note that more students in each school receive access to *Surala Ninja!* software than our baseline survey sample.

[14] We have 8 schools with <60 students in our sample

[15] The growth mindset is a term developed by psychologist Dweck (2016). Individuals with a growth mindset believe that their talents can be developed through hard work, good strategies, and input from others. The opposite of a growth mindset is a fixed mindset, in which individuals believe otherwise.

| | | | |
|---|---|---|---|
| | | | ● Students' learning habits and motivation, especially in studying mathematics<br>● Students' belief in a growth-oriented mindset |
| 3 | Teachers | Teacher content and pedagogical knowledge tests on mathematics | ● Teacher's knowledge about mathematics up to grade 7 curriculum<br>● Teacher's knowledge and ability on the pedagogical techniques on teaching mathematics for junior high school students |
| 4 | | Teacher questionnaires | ● Teacher's ability to integrate technology and ed-tech products/services into mathematics lesson plan<br>● Teacher's belief in a learning experience focused on the student's capabilities<br>● Teacher's belief and perception towards growth-oriented mindset |
| 5 | | One-on-one interview | ● Teacher's educational background<br>● Teacher's employment status<br>● Teaching experience<br>● Teaching practices<br>● Familiarity in tech-assisted education |
| 6 | | Classroom observation | ● Teachers' teaching practices<br>● Teachers' pedagogical skills in mathematics |
| 7 | Principal/school administration staff | One-on-one interview | ● School infrastructure, especially those related to |

| | | | |
|---|---|---|---|
| | | | the implementation of educational technology products and services<br>● Maintenance of school infrastructure |

Instruments were developed by the research and survey team from an Indonesian research institute that has worked intensively in education. The instruments were a mix of existing sample questions from the institution's question item bank and questions from the assessments for Trends in International Mathematics and Science Study (TIMSS).[16] All example questions from TIMSS are contextualized further to suit the needs of this project. The instruments contain numeracy and literacy materials taught to students in grades six and seven; 50% of the questions cover materials taught in grade 6 and 50% in grade 7. Regarding the skill set being tested in the instruments, approximately 50% of the questions will test foundational skills, and 50% will test higher-order thinking skills.

The endline instruments, except the classroom observation module, were pre-tested during our instrument pilot/trial in Kendal, Central Java, during 10 -16 June 2022. We conducted the pilot in four schools that will not participate in our baseline, interventions, or endline surveys. After pre-testing the instruments, we edited the teacher and student questionnaires on-site after the instrument pilot was completed. The instruments were revised after the collected data was analyzed for the student's and teachers' tests. Based on the results of the data analysis, we shortened the instruments and adjusted the difficulty level based on the results of the pilot.  On the other hand, the classroom observation module has been piloted in Bogor, West Java, and has been previously used in a study with similar population characteristics.

### End-line Survey Participants

The participants of the end-line study will be the students, teachers, and principals/school staff invited to participate in the baseline survey. We will include an additional sample of students and teachers to measure spillovers. We plan to include 166 extra seventh-grade classrooms (with each classroom having approximately 35 students) and 30 math teachers, with no additional samples for the principal/school staff. Thus, we plan to include approximately 20,000 students, 330 teachers, and 150 principals/school staff in the endline survey.

[16] TIMSS provides reliable and timely trend data on the mathematics and science achievement of U.S. students compared to that of students in other countries. https://nces.ed.gov/timss/

## Timeline of Surveys

The endline data collection will be conducted from the first week of March 2023 until the second week of April 2023. During the first two weeks of data collection (the first until the third week of March 2023), classroom observation will be conducted for all classes led by eligible teachers for our survey, alongside the interviews with school principals. Data collection will continue in the fourth week of March until the second week of April 2023, when student and teacher assessments, questionnaires, and teacher interviews will be conducted.

## Data management

***Data Security and Confidentiality.*** The project team will use the following procedures to maintain the security of the collected data:

1. The participants' personally identifiable information (PII) is only used as identification information. All PII datasets will be stored in encrypted, password-protected/locked containers. The participants' PII will not be used during data analysis and reporting and will not be published in any associated publications of this study.
2. Upon completion of the study, the data collected will be directly cleaned to remove any unnecessary PII for data processing and analysis. The project team has determined the following tenure to store the data collected in this study:
    a. **Paper surveys containing personally identifiable information** (**PII**) will be stored for three years after the completion of the endline survey.
    b. **Paper surveys without PII** will be stored for three years after the completion of the endline survey.
    c. **Digitized data with PII** will be stored for ten years after the completion of study
    d. **Digitized de-identified data** will be stored permanently
    e. **Audio and video recordings** will be stored for a maximum of three years after the end of the study or until the paper of this study is published, whichever comes first.
3. Access to the data collected in the study will be limited to the project team (i.e., principal investigators, J-PAL SEA, and The SMERU Research Institute). It will not be shared with other unrelated third parties unless required by law.

ADBI and Tanoto Foundation will own the processed data, as these organizations fund the project activities. They will be used as the basis for future publications related to this study, be it working papers, conference materials, or journal articles.

# Empirical Analysis

## Outcome Variables

Our **primary outcomes of interest** in this study are the students' numeracy skills. We also want to understand the impact of the interventions on their motivation and interest in mathematics. The primary outcomes of interest are the grade-adjusted standardized scores from the student learning assessments (SLA) results for numeracy.

***Heterogeneity Analysis.*** We are also interested in conducting a heterogeneity analysis by gender, student's socioeconomic status, baseline learning outcomes (above v. below median), and the school's baseline quality (mean of student learning outcomes at the school level). For the teachers, we will examine these effects by teachers' socioeconomic status, initial tech-efficacy, and initial mathematics and pedagogical skills level.

## Empirical Specification

We will estimate ordinary least squares on the following base specification to estimate the intent-to-treat (ITT) for outcomes with both endline and baseline measures:

$$Y_{i1} = \alpha + \beta_1 T_{HT} + \beta_2 T_{HTHT} + Y_{i0} + X\delta + \eta_s + \varepsilon_{it} \tag{1}$$

where the $Y_{i1}$ is the outcome variable at endline; T is the treatment status for HT and HTHT respectively; *i* and *t* indexes individual, time indicator of (0 or 1 indicates baseline or endline); and $\eta_s$ is the strata fixed effects. X is a vector of control variables that will include exogenous and predetermined variables of sex and age (for all), parents' education (for students), and completed education level (for teachers and parents). The inclusion of control variables is to increase precision. Standard errors will be clustered at the school level.

For outcomes without baseline measures, i.e., teaching practice, we will estimate the same model but exclude $Y_{io}$, as written below:

$$Y_{i1} = \alpha + \beta_1 T_{HT} + \beta_2 T_{HTHT} + X\delta + \eta_s + \varepsilon_{it} \tag{2}$$

We plan to estimate impact heterogeneity by student and teacher characteristics. First, we will conduct a gender analysis (for both students and teachers). Second, we study how students' baseline math skills affect the effectiveness of the interventions. Third, we study the heterogeneous impacts of the students' home learning environment (proxied by parental education). Fourth, we examined the heterogeneous impacts of both students' and teachers' familiarity with similar education technology at baseline. Finally, we study how teachers' age (as a proxy for willingness to learn new skills) and status (permanent v. contract) would differentially affect the impacts.

The heterogeneity analysis will be conducted by interacting the treatment variables with each of the heterogeneous variables described previously, namely:

$$Y_{i1} = \alpha + \alpha_H HetVar + \beta_1 T_{HT} + \beta_1 (T_{HT} \times HetVar) + \beta_2 T_{HTHT} + \beta_2 (T_{HTHT} \times HetVar) + \\ + Y_{i0} + X\delta + \eta_s + \varepsilon_{it} \quad (3)$$

where all other variables are as above, and *HetVar* is the heterogeneity variable. Similar to the base specification, standard errors will be clustered at the school level to analyze students' outcomes. Given that we will have many outcome variables, we will compute the sharpened q-value proposed by Anderson (2008).

Spillover to the control group is unlikely, given the following reasons. First, the *Surala Ninja!* software is subscription-based and thus limited to only the students and teachers in the treatment schools. Second, the control group consists of students and teachers from different schools. However, spillover to non-participating teachers or students within the treatment schools is likely. While this type of spillover is not a source of bias for the impact estimates, measuring it is essential for policy purposes. To measure whether spillover occurs, we plan to add three groups in the endline survey: (i) students who do not receive the *Surala Ninja!* software, but taught by teachers who participate in the intervention, if any exist; (ii) grade 7 mathematics teachers who are not selected to participate in the intervention; (iii) a randomly selected classroom taught by the non-participating teacher.

Attrition from the program in the form of schools or teachers deciding to drop out is unlikely because the pilot received full support from the Ministry of Education and the respective local education agencies. Of the 150 schools selected to participate in the baseline survey, only one declined. Similarly, our baseline and endline surveys will be done within one school year. Given the negligible dropout rates between grades in Indonesia (Dharmawan & Suryadarma, 2021), we do not expect significant attrition at the student level.

Non-compliance by teachers could be a significant issue. First, they may decide to stop or reduce the *Surala Ninja!* classes. Second, they may not practice the high-touch material. To minimize the first issue, the implementers put a continuous support system into the design of the interventions. However, this implies our baseline estimates should be considered as measuring intent-to-treat (ITT) estimates.

We will also estimate a dose-response, which could no longer rely on the experimental design to ascertain causality but would still be informative. We will use the *Surala Ninja!* server record on login, session length, progress, and keystrokes at the student and teacher levels. Finally, this information will allow us to understand the correlates of teacher and student interest in using the interventions. These correlations are highly policy-relevant, as they inform policymakers on the probability of adopting technology and new teaching techniques among public school teachers and students, should these be offered.

# Research Team

## Principal Investigators

The principal investigators of this study are (written in alphabetical order of last names):

- **Arya B. Gaduh** (Co-Principal Investigator). Arya is an Associate Professor of Economics at the Sam M. Walton College of Business, University of Arkansas, Fayetteville. He is also a research associate at the National Bureau of Economic Research (NBER) and an affiliated professor of The Abdul Latif Jameel Poverty Action Lab (J-PAL).
- **Takiko Igarashi** (Co-Principal Investigator). Takiko is a Project Consultant at the Asian Development Bank Institute (ADBI).
- **Milda Irhamni** (Co-Principal Investigator). Milda is currently an independent researcher.
- **Gumilang Aryo Sahadewo** (Co-Principal Investigator). Gumilang is a Research Fellow at The Abdul Latif Jameel Poverty Action Lab Southeast Asia (J-PAL SEA - LPEM FEB UI) and an Assistant Professor at the Department of Economics, Gadjah Mada University.
- **Daniel Suryadarma** (Lead Principal Investigator). Daniel is a Research Fellow at the Asian Development Bank Institute (ADBI).

## Research Assistants

As of the latest draft of this pre-analysis plan, the research assistants who are currently involved in this study are (written in alphabetical order of last names):

- **Abdul Latif Jameel Poverty Action Lab Southeast Asia (J-PAL SEA)**
    - **Indriani Pratiwi** (July 2022 - present), Research Manager, The Abdul Latif Jameel Poverty Action Lab Southeast Asia (J-PAL SEA - LPEM FEB UI)
    - **Miranda Aisha Putri** (January 2022 - present), Research Associate, The Abdul Latif Jameel Poverty Action Lab Southeast Asia (J-PAL SEA - LPEM FEB UI)
- **The SMERU Research Institute (for endline study)**
    - **Arjuni Rahmi Barasa** (March 2022 - present), Junior Researcher, The SMERU Research Institute

- **Luhur Bima** (March 2022 - present), Senior Researcher, The SMERU Research Institute
- **Fauzan Kemal Musthofa** (August 2022 - present), Senior Researcher, The SMERU Research Institute
- **Risa Wardatun Nihayah** (March 2022 - present), Researcher, The SMERU Research Institute
- **Asri Yusrina** (March 2022 - present), Senior Researcher, The SMERU Research Institute

Team members might change as the project enters its next steps.

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