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Pre-analysis plan of "Impact on learning outcome by effective use of mathematics textbook structured for increasing 'learning time'[1]"

General Notes

1. This document outlines an analysis plan regarding causal effects of the treatment at the end-line and at the follow up survey. Control group will receive treatment on the next school year of the end-line survey. School calendar starts from mid-January and end at the end of October of the year. The baseline survey is conducted from January to February 2018, and the end-line survey is carried out at the end of the school year, from September to October 2018. The follow up survey will be implemented one year after the end-line survey, from September to October 2019.

2. Surveys are conducted for the 2nd grade of primary school and the 1st grade of junior high school in 2018, and continued to follow the same student at the 3rd grade and the 2nd grade in 2019. At the baseline survey, one class at each grade is randomly chosen if the school has several classes on those grades. The teachers at the baseline survey will be followed at the end-line and the follow-up survey; however, if the teacher of a class is moved to the other school or in charge of the other grade, the current teacher in charge of the class will be surveyed at the end-line and follow up survey. If the teacher at the baseline survey is moved to the other class of the same grade at the same school, the teacher will be followed.

3. Definitions of terms

(1) Learning outcome is measured by paper tests. Z-scores of test scores are calculated by standardizing to the values of control group. There are 20 items in the test at each grade for the 2nd grade and the 7th grade. The test for the 3rd grade and the 8th grade are composed 25 items. Each 5 items for the 3rd grade and the 8th grade cover the content of the previous year, that is, the 2nd grade and the 8th grade. The definition of cognitive domains such as "knowledge", "application" and "reasoning" is based on that of TIMSS. The areas of mathematics in primary education are i) number and calculation, ii) quantity and measurement, iii) geometry and iv) numerical relation. The areas of mathematics in junior secondary education are i) number and operation, ii) geometry and iii) function.

(2) In this paper, we call the allocated time that aims "student engaged time" as "learning time". The learning time is allocated by teacher in the mathematics class or by the student at home. Learning time in the

[1] Squires, Huitt and Segars (1983) defines "student engaged time" as "a measure of involvement that takes into consideration both allocated time and engagement rate (that is, student engaged time = allocated time×engagement rate)". Involvement means "the amount of time that student spends actively involved in learning a specific subject matter." "Involvement has two aspects: how much time is provided by the teacher (allocated time), and how well students are engaged during the time provided (engagement rate). (ibid). This paper calls the allocated time that aims "student engaged time" as "learning time".

mathematics class is the time allocated by teacher for self-problem solving, pair or group work on problem solving among students in the mathematics class. The learning time is measured by lesson observation. Surveyors counted the learning time, if at least half of the students in the class conduct either self-problem solving, pair or group work on problem solving among students. Learning time at home is the time allocated for self-problem solving at home. The learning time is measured by a questionnaire given to students.

(3) Student support activity for their learning in a class is defined as the one that enhances them to concentrate on or facilitate problem solving (checking notebook, telling students to consult with their classmates, giving suggestions or clues, asking children to do the same exercise if they gave wrong answer).

(4) The degree of preparation of teachers for the mathematics class is measured by the aspects of i) elaboration of annual teaching plan, ii) periodical review of annual teaching plan based on the progress, iii) reading teachers' guide, and iv) solving problems that will be posed in a class based through questionnaire given to teachers.

(5) Motivation and value of students on learning mathematics are measured by degree of like math, degree of like solving math, degree of understanding math class, degree of usefulness of math in life through questionnaire given to students.

(6) Assets of students at home are measured by the questionnaire given to students. Items of assets of study in general include i) mathematics textbook and ii) notebook. Items of assets at home include i) smartphone, ii) computer, iii) refrigerator, iv) car, v) TV, vi) flush toilet, and vii) using wood / gas / electricity for cooking.

4. Regression frameworks

(1) Regarding the outcomes variables of student *i* for the analysis of the end-line survey, the following regression frameworks are used to identify treatment effect in comparison to the baseline values.

$$T_{ijk}(Y_1) = \alpha_1 + \gamma_1 T_{ijk}(Y_0) + \delta_{1A} GroupA + \beta_{1c} C_{ijk} + \beta_{1p} P_{mjk} + \beta_{1s} S_k + \beta_{1D} D_k + \varepsilon_{1jk} + \varepsilon_{1ijk}: \text{1-(1)}$$

$$T_{ijk}(Y_1) = \alpha_1 + \gamma_1 T_{ijk}(Y_0) + \delta_{1A} GroupA + \delta_{1A(BL)} GroupA \times T_{ijk}(Y_0) + \beta_{1c} C_{ijk} + \beta_{1p} P_{mjk} + \beta_{1s} S_k + \beta_{1D} D_k + \varepsilon_{1jk} + \varepsilon_{1ijk} \ : \text{1-(2)}$$

$$T_{ijk}(Y_1) = \alpha_1 + \gamma_1 T_{ijk}(Y_0) + \delta_{1A} GroupA + \delta_{1A(ASSET)} GroupA \times ASSET_{ijk} + \beta_{1c} C_{ijk} + \beta_{1p} P_{mjk} + \beta_{1s} S_k + \beta_{1D} D_k + \varepsilon_{1jk} + \varepsilon_{1ijk} \ : \text{1-(3)}$$

$T_{ijk}(Y_1)$ represents the end-line value of an outcome for student *i* of *j*th grade in school *k*, and $T_{ijk}(Y_0)$ represents the baseline value of an outcome for student *i* of *j*th grade in school *k*. Regarding test scores for outcome variable, Z scores are calculated as mentioned in the general note 3 (1). $GroupA$ is an indicator variable for whether school *k* was treated with the interventions. $GroupA \times ASSET_{ijk}$ is an interaction term of $GroupA$ and variable of number of assets at home of student *i* of grade *j* at school *k*. $GroupA \times T_{ijk}(Y_0)$ is an interaction term of $GroupA$ and baseline test score of student *i* of grade *j* at school *k*. $T_{ijk}(Y_0)$ and $ASSET_{ijk}$ in the interaction term are centered at zero. C_i are characteristics of student *i* of grade *j* at school *k* such as age, gender, shift at school (morning or afternoon) and number of brothers or sisters at the baseline, and characteristics of family of student *i* of grade *j* at school *k* such as number of assets at home at the baseline. P_{mj} are characteristics of the headmaster and teacher *m* of *j*th grade at school *k* such as age, gender, educational qualification. S_k are characteristics of school *k* such as number of students, school infrastructure, school meal and remedial activity at the baseline. D_k are department dummy and rural / urban dummy of school *k*. Standard errors are clustered at the school level.

(2) Regarding the outcomes variables of student *i* for the analysis of follow up survey, the following regression frameworks are used to identify treatment effect in comparison to the baseline values. Control variables of the regression frameworks are values of baseline.

$$T_{ijk}(Y_2) = \alpha_2 + \gamma_2 T_{ijk}(Y_0) + \delta_{2A} GroupA + \beta_{2c} C_{ijk} + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2ijk} \text{: 2-(1)}$$

$$T_{ijk}(Y_2) = \alpha_2 + \gamma_2 T_{ijk}(Y_0) + \delta_{2A} GroupA + \delta_{2AY2} GroupA \times Y2 + \beta_{2c} C_{ijk} + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \beta_{y2} Y2 + \varepsilon_{2jk} + \varepsilon_{2ijk} \text{: 2-(2)}$$

$$T_{ijk}(Y_2) = \alpha_2 + \gamma_2 T_{ijk}(Y_0) + \delta_{2A} GroupA + \delta_{2A(BL)} GroupA \times T_{ijk}(Y_0) + \beta_{2c} C_{ijk} + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2ijk} \text{: 2-(3)}$$

$$T_{ijk}(Y_2) = \alpha_2 + \gamma_2 T_{ijk}(Y_0) + \delta_{2A} GroupA + \delta_{2A(ASSET)} GroupA \times ASSET_{ijk} + \beta_{2c} C_{ijk} + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2ijk} \text{: 2-(4)}$$

$T_{ijk}(Y_2)$ represents the follow up survey value of an outcome for student *i* of *j*th grade in school *k*. $GroupA \times T_{ijk}(Y_0)$ is an interaction term of $GroupA$ and $T_{ijk}(Y_0)$. $GroupA \times ASSET_{ijk}$ is an interaction term of $GroupA$ and $ASSET_{ijk}$. $T_{ijk}(Y_0)$ and $ASSET_{ijk}$ in the interaction term are centered at zero. $Y2$ is a dummy variable of the second year of the survey. $GroupA \times Y2$ is an interaction term of $GroupA$ and $Y2$. The rest of variables are same as described above.

(3) Regarding the outcomes variables of student *i* for the analysis of follow up survey, it is of interest to identify the treatment effect in comparison to the end-line values, i.e., the 2nd year gain between the values of the end-line and the follow up survey. However, as Das (2013) mentioned, a simple replacement

of Y_0 in equations 2-(1), 2-(2), 2-(3), and 2-(4) by Y_1 suffers from the fact that the value of end-line survey of the treatment group will be correlated with the intervention, which might prevent us from accurately estimating the 2nd year gain. To avoid this problem, γ_{2j} associated with Y_1 is estimated first by regression framework 1-(1)' using only the data of control group (Das, 2013).

$T_{ijk}(Y_2) = \alpha_2 + \gamma_{2j}T_{ijk}(Y_1) + \beta_{2c}C_{ijk} + \beta_{2p}P_{mjk} + \beta_{2s}S_k + \beta_{2D}D_k + \varepsilon_{2jk} + \varepsilon_{2ijk}$: 1-(1)'

Then the 2nd year gain between the values of the end-line and the follow up survey will be analyzed with the following regression framework. $T_{ijk}(Y_2) - \hat{\gamma}_{2j}T_{ijk}(Y_1)$ represents the difference of variable between follow-up survey and end-line on outcome variables of child *i* of *j*th grade in school *k*. $\hat{\gamma}_{2j}$is the fitted parameter estimated by the regression 1-(1)' as written above. The rest of variables are same as described above.

$T_{ijk}(Y_2) - \hat{\gamma}_{2j}T_{ijk}(Y_1) = \alpha_2 + \delta_{2A}GroupA + \beta_{2c}C_{ijk} + \beta_{2p}P_{mjk} + \beta_{2s}S_k + \beta_{2D}D_k + \varepsilon_{2jk} + \varepsilon_{2ijk}$: 3-(1)

$T_{ijk}(Y_2) - \hat{\gamma}_{2j}T_{ijk}(Y_1) = \alpha_2 + \delta_{2A}GroupA + \delta_{2A(BL)}GroupA \times T_{ijk}(Y_0) + \beta_{2c}C_{ijk} + \beta_{2p}P_{mjk} + \beta_{2s}S_k + \beta_{2D}D_k + \varepsilon_{2jk} + \varepsilon_{2jjk}$: 3-(2)

$T_{ijk}(Y_2) - \hat{\gamma}_{2j}T_{ijk}(Y_1) = \alpha_2 + \delta_{2A}GroupA + \delta_{2A(ASSET)}GroupA \times ASSET_{ijk} + \beta_{2c}C_{ijk} + \beta_{2p}P_{mjk} + \beta_{2s}S_k + \beta_{2D}D_k + \varepsilon_{2jk} + \varepsilon_{2ijk}$: 3-(3)

(4) Regarding the outcomes variables of teachers for the analysis of the end-line survey, the following regression frameworks are used.

$L_{mjk}(Y_1) = \alpha_1 + \lambda_{1j}L_{mjk}(Y_0) + \delta_{1A}GroupA + \beta_{1p}P_{mjk} + \beta_{1s}S_k + \beta_{1D}D_k + \varepsilon_{1mjk}$: 4-(1)

$L_{mjk}(Y_1) = \alpha_1 + \lambda_{1j}L_{mjk}(Y_0) + \delta_{1A}GroupA + \delta_{1A(P)}GroupA \times P^*_{mjk} + \beta_{1p}P_{mjk} + \beta_{1s}S_k + \beta_{1D}D_k + \varepsilon_{1mjk}$: 4-(2)

$L_{ijk}(Y_1)$ represents the end-line value of an outcome for teacher *m* of *j*th grade in school *k*, and $L_{mjk}(Y_0)$ represents the baseline value of an outcome for teacher *m* of *j*th grade in school *k*. $\delta_{1A}GroupA \times P^*_{mjk}$ are interaction terms of $GroupA$ and characteristics of the teacher such as experience year and specialty. The rest of variable are same as described above. Standard errors are clustered at the school level.

(5) Regarding the outcomes variables of teachers for the analysis of the follow up survey, we use the following regression frameworks. Control variables of the regression frameworks are values of baseline.

$L_{mjk}(Y_2) = \alpha_2 + \lambda_{2j}L_{mjk}(Y_0) + \delta_{2A}GroupA + \beta_{2p}P_{mjk} + \beta_{2s}S_k + \beta_{2D}D_k + \varepsilon_{2mjk}$: 5-(1)

$L_{mjk}(Y_2) = \alpha_2 + \lambda_{2j} L_{mjk}(Y_0) + \delta_{2A} GroupA + \delta_{2A(P)} GroupA \times P^*_{mjk} + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2mjk}$: 5-(2)

$L_{mjk}(Y_2) = \alpha_2 + \lambda_{2j} L_{mjk}(Y_0) + \delta_{2A} GroupA + \delta_{2AY2} GroupA \times Y2 + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \beta_{2Y} Y2 + \varepsilon_{2jk} + \varepsilon_{2mjk}$: 5-(3)

(6) To accurately estimate the 2nd year gain between the teacher outcomes of the end-line and the follow up survey, a two-step model similar to the student outcomes is adopted, because the value of end-line survey of the treatment group will be correlated with the intervention, as Das (2013) mentioned. λ_{2j} associated with Y_1 is first estimated by regression framework 4-(1)' using only the data of control group (Das, 2013).

$L_{mjk}(Y_2) = \alpha_2 + \lambda_{2j} L_{mjk}(Y_1) + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2ijk}$: 4-(1)'

Then the 2nd year gain between the values of the end-line and the follow up survey will be analyzed with the following regression framework. $L_{mjk}(Y_2) - \hat{\lambda}_{2j} L_{mjk}(Y_1)$ represents the difference of variable between follow-up survey and end-line on outcome variables of teacher *m* of *j*th grade in school *k*. $\hat{\lambda}_{2j}$is the fitted parameter estimated by the regression 4-(1)' as written above. The rest of variables are same as described above.

$L_{mjk}(Y_2) - \hat{\lambda}_{2j} L_{mjk}(Y_1) = \alpha_2 + \delta_{2A} GroupA + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2ijk}$: 3-(1)

$L_{mjk}(Y_2) - \hat{\lambda}_{2j} L_{mjk}(Y_1) = \alpha_2 + \delta_{2A} GroupA + \delta_{2A(BL)} GroupA \times L_{mjk}(Y_0) + \beta_{2p} P_{mjk} + \beta_{2s} S_k + \beta_{2D} D_k + \varepsilon_{2jk} + \varepsilon_{2jjk}$: 3-(2)

5. Regression analysis will be conducted in OLS, and also in GLS to gain more efficient estimator. The increase of learning time, caused by the intervention, on learning outcome will be estimated by 2SLS.

6. Cost effectiveness of the intervention will be analyzed according to the J-PAL costing guideline.

Overall Outcomes and Hypotheses

Main Outcome 1-1: The total Z-Score of correct responses of math test, and the sub-total of Z score of each area of mathematics or cognitive domain at the end-line survey

Hypothesis: Treatment will generate a positive effect on students' test score. The effect of both of the interaction terms on baseline score or asset will not be positive. Regarding the 2nd grade students, score of the domain of knowledge of number and calculation will be improved. Regarding the 7th grade students, score of

the domain of knowledge of number and operations will be improved.

Tests: Regress outcomes using 1-(1), 1-(2) and 1-(3), and evaluate the significance of each coefficient.

Main Outcome 1-2: The total Z-Score of correct responses of math test, and the sub-total of Z score of each area of mathematics or cognitive domain at the follow up survey

Hypothesis: Treatment will generate a positive effect on students' test score. The effect of both of the interaction terms on baseline score or asset will not be positive. The effect of the interaction term on the 2nd year dummy will not be negative. The subtotal of Z Scores of cognitive domain on application and that of reasoning will be improved.

Tests: Regress outcomes using 2-(1), 2-(2), 2-(3) and 2-(4), and evaluate the significance of each coefficient.

Main Outcome 1-3: Difference of the total Z-Score of correct responses of math tests at the end-line and follow up survey, and the difference of the subtotal of Z-Score of each area of mathematics and cognitive domain.

Hypothesis: The treatment will generate a cumulative positive effect on students' test score. The effect of both of the interaction terms on baseline score or asset will not be positive. Scores of cognitive domain on application and that of reasoning will be improved.

Tests: Regress outcomes using 3-(1), 3-(2) and 3-(3), and evaluate the significance of each coefficient.

Main Outcome 2-1: Learning time in a mathematics class at the end-line survey.

Hypothesis: Treatment will generate a positive effect on learning time at a mathematics class. The percentage of teacher who allocates student engaged time more than 20 minutes in a class of 45 minutes will be significantly increased in the treatment group. The effect of the interaction terms on number of experience year or qualification will not be positive.

Tests: Regress outcomes using 4-(1) and 4-(2) and evaluate the significance of each coefficient. 2SLS will be conducted to identify the causal effect from the intervention to the increase in learning time at class, and from the learning time increase to the improvement of learning outcome.

Main Outcome 2-2: Learning time in a mathematics class at the follow up survey.

Hypothesis: Treatment will generate a positive effect on learning time in a mathematics class. The percentage

of teacher who allocates student engaged time more than 20 minutes in a class of 45 minutes will be significantly increased in the treatment group. The effect of the interaction terms on number of experience year, qualification and specialty will not be positive. The effect of the interaction term on 2nd year dummy will not be negative.

Tests: Regress outcomes using 5-(1), 5-(2), 5-(3), and evaluate the significance of each coefficient. 2SLS will be conducted to identify the causal effect from the intervention to the increase in learning time at class, and from the learning time increase to the improvement of learning outcome.

Main Outcome 2-3: Difference of learning time in a mathematics class at the end-line and the follow up survey.

Hypothesis: Treatment will generate a cumulative positive effect on learning time in a mathematics class. The percentage of teacher who allocates student engaged time more than 20 minutes in a class of 45 minutes will be significantly increased in the treatment group. The effect of the interaction terms on number of experience year, qualification and specialty will not be positive.

Tests: Regress outcomes using 6-(1), 6-(2), and evaluate the significance of each coefficient.

Additional Outcome 1-1: Motivation and value of learning mathematics at the end-line survey, and the follow up survey

Hypothesis: Treatment will generate a positive effect on value of learning mathematics of students. The effect of the interaction terms on baseline score or asset will not be positive.

Tests: Regress outcomes using 1-(1), 1-(2), 1-(3), 2-(1), 2-(2), 2-(3), and 2-(4), and evaluate the significance of each coefficient.

Additional Outcome 1-2: Learning time at home and learning method of mathematics (ask your family, consult friends, read books, check your note book) at the end-line survey, and the follow up survey

Hypothesis: Treatment will generate a positive effect on learning time at home and learning method of mathematics of students. The effect of the interaction terms on baseline score or asset will not be positive.

Tests: Regress outcomes using 1-(1), 1-(2), 1-(3), 2-(1), 2-(2), 2-(3) and 2-(4), and evaluate the significance of each coefficient. 2SLS will be conducted to identify the causal effect from the intervention to the increase in learning time at home, and from the learning time increase to the improvement of learning outcome.

Additional Outcome 1-3: Family support to students learning of mathematics at the end-line and follow-up survey

Hypothesis: Treatment will generate a positive effect on students' learning of mathematics at home. The effect of the interaction terms on baseline score or asset will not be positive.

Tests: Regress outcomes using 1-(1), 1-(2), 1-(3), 2-(1), 2-(2), 2-(3) and 2-(4), and evaluate the significance of each coefficient.

Additional Outcome 2-1: Preparation by teachers for mathematics class at the end-line survey, and the follow up survey

Hypothesis: Treatment will generate a positive effect on preparation of teachers for mathematics class. The effect of the interaction terms on number of experience year, qualification and specialty will not be positive.

Tests: Regress outcomes using 4-(1), 4-(2), 5-(1), 5-(2) and 5-(3), and evaluate the significance of each coefficient.

Additional Outcome 2-2: Students support activity by teacher in a mathematics class at the end-line survey and the follow up survey

Hypothesis: Treatment will generate a positive effect on student support activity at a mathematics class. The effect of the interaction terms on number of experience year or qualification will not be positive.

Tests: Regress outcomes using 4-(1), 4-(2), 5-(1), 5-(2), 5-(3), and evaluate the significance of each coefficient.

END

Reference:

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