Pre-Analysis Plan

Delivering remote learning using a low-tech solution: Evidence from an RCT during school closures

Hashibul Hassan[*]   Asad Islam[†]   Michael Vlassopoulos[‡]   Liang Choon Wang[§]

Abstract

In this document, we provide the intervention details, research design, and outcome analysis plan for the impact evaluation of a basic mobile phone-based educational program in rural South-West Bangladesh. During the prolonged school closure because of the COVID-19 pandemic, most children in rural Bangladesh are missing out on formal education as they have very limited access to online and other forms of distance education. We develop a set of audio lessons using an Interactive Radio Instruction (IRI) methodology – a method that allows learners to stop and react to questions and exercises through verbal response and to engage in physical and intellectual activities with a 'special helper', such as an adult household member, while the program is 'on the air'. We deliver these lessons to children in grades two to four over 15 weeks via basic mobile phones using an Interactive Voice Response (IVR) system as the basic mobile phone penetration rate in rural Bangladesh is significantly higher than other one-way technologies such as radio and television. In this study, we examine whether providing remote learning opportunities through IVR improves children's cognitive and noncognitive skills.

JEL: I21, I24, I25, O15.

Keywords: Mobile-based education, Interactive Voice Response (IVR), COVID-19, Impact Evaluation, Randomized Experiment, Bangladesh, Rural Children, Primary Education.

1 Context, Problem Statement and Aims

Despite high primary school enrolment rates, the learning outcomes of students in Bangladesh are poor, especially in rural areas (Islam, 2019). Approximately 44% of students cannot read simple words after completion of grade 1 (USAID, 2021). In the National Student Assessment test 2017, more than half of fifth-graders failed to meet grade-level proficiency in literacy and numeracy (NSA, 2017). This situation is likely to have worsened during the COVID-19 pandemic, as children are missing out on all forms of formal schooling, given that schools have been closed since March 2020. Learning outcomes of children from poor households and in rural areas are likely to suffer the most during school closures as they lack other non-school educational inputs, because of their low socio-economic status (SES).

During the current school closure, the government of Bangladesh provides distance education through television and radio to counteract the negative effects. These asynchronous lessons are non-interactive i.e., the instructor solely shows and/or narrates solutions to various problems from textbooks. Literature suggests that students usually retain around 10% of what they read, 26% of what they listen to, 50% of what they listen to and see, 90% of what they say and do (Silcox, 1995). Therefore, one-way communication platforms, such as television, radio, and basic feature phone, can be more effective in delivering education if interactive pedagogy is integrated. A plausible solution to this integration can be the use of Interactive Radio Instruction (IRI) methodology, which is a method to turn a typically one-way technology into a tool for active learning. It requires that learners stop and react to questions and exercises through verbal response to radio characters, group work, and physical and intellectual activities while the program is 'on the air' (Bosch et al., 2002). IRI generally follows the constructivist approach of teaching where children develop imagination and make their own knowledge that is determined by the experiences of the learner (Elliott et al., 2000). It has been developed to use in the classroom to offset inadequate training of teachers, poor learning outcomes among children, and lack of resources.

In this educational intervention, we use audio lessons that are developed using the Interactive Radio Instruction (IRI) methodology and are delivered via basic feature phones. We modified the original design of IRI in two ways. Firstly, we use an Interactive Voice Response (IVR) system of telecommunication technology to deliver IRI-based lessons. There are three main reasons for this choice of medium. The first is *access*: only 44% of rural households own a television and only 3% own and listen to the radio in Bangladesh (UNICEF, 2019). On the other hand, 94% of households own a basic mobile phone. We take advantage of this high penetration of mobile phones to offer pre-recorded interactive lessons. This solution, if effective, can be scaled up at a low cost. The second is *tracing*: it is almost impossible to trace who is listening to radio programs or watching television programs and who is not, which is problematic for a rigorous impact study. The third is *flexibility*: unlike television and radio, IVR lessons can be accessed anytime during the teaching period, allowing children to learn with convenience. This flexible delivery method addresses the resource constraints rural households typically face, such as having only one phone in each household, and unstable

mobile networks and electricity supply. Moreover, parents could schedule their time for children's homeschooling with greater ease.

Secondly, we rely on the parent (mostly the mother) or an adult member in the household as a 'special helper', who will phone the program's number and select the desired lesson by traversing the IVR. Once the lesson is selected, the parent puts the call on speaker or handsfree mode (this feature is available in any type of mobile handset) and listens to the lesson together with the child. During the lesson, there are different instructions for the child to follow and activities for the child to do with the parent. None of these activities requires a high level of competence. However, we provide a program booklet (in Bangla) and a brief to the parent about their role before the program begins (See Figure 1 for the timeline of this intervention).

The household environment plays a critical role in a child's education. However, most education policies primarily focus on school-based interventions as it is believed that it is more feasible to improve schools than to intervene at the household level at scale (Muralidharan and Singh, 2021). The current school closure has sharply increased the need for parental involvement in children's education. But parents, especially those from a low socio-economic background, do not necessarily have the ability, skill, and confidence to support their children's learning and to guide them through the school curriculum (Pensiero et al., 2020, Agostinelli et al., 2020, Biswas et al., 2020). While these parents need the support the most, they are getting the least due to poor access to ICT technology. Though the use of basic mobile phones for children's education has increased exponentially during the pandemic, it is quite limited to SMS reminders or brief calls to the parents to follow up on the homework (Angrist et al., 2020, Muralidharan and Singh, 2021). In this study, we expand the use of the basic mobile phone as a pedagogical tool to support children's education in out-of-school settings. During this current school closure, we expect this intervention to reduce the learning loss of learners and guide the interaction of learners with their parents which may partially mitigate the lack of social interaction.

Various evaluations between 1975 to 2000 demonstrated that IRI improved learning outcomes in conventional classrooms by between 10% and 20% when compared with control classrooms (Ho and Thukral, 2009, Anzalone and Bosch, 2005). However, little is known about the effectiveness of IRI for out-of-school learners. It is immensely important to examine the efficacy of interactive instructions delivered via one-way communication technology as it has the potential to reach a significant portion of people around the world who live in extremely low-resource settings. If it is found to be an effective educational intervention, it can be scaled up at low costs to provide basic literacy and numeracy to hard-to-reach people. To the best of our knowledge, this study will be the first study to assess the effectiveness of an IRI-based educational intervention to out-of-school learners via basic feature phones.

We collaborate with a local research-focused NGO, Global Development and Research Initiative (GDRI) Foundation, to implement this intervention. GDRI has recently completed a large-scale survey and assessment of 7000+ children in 223 villages in the southwestern part of Bangladesh. We will leverage the sample and rich set of data for this project to implement

and evaluate the causal impact of an IRI-based educational program on the cognitive and noncognitive outcomes of primary graders. We also investigate the heterogeneous effects of school interruption and the IRI-based program on learners of different gender and baseline literacy and numeracy skills.

2   Intervention and Research Design

2.1   Intervention and sample

In this intervention, we have established two Interactive Voice Response (IVR) based toll-free numbers to deliver interactive lessons to primary graders. Figure A1 and Figure A2 in the appendix portray the IVR flow journey of the participating parent-child dyads. This intervention contains three modules divided into 75 lessons, each lesson with a duration of 16 to 18 minutes. These modules focus on numeracy, literacy, and a set of noncognitive skills. The contents of these modules are listed in Table 1. We have designed these modules exclusively for this program with the support of two other international organizations[1] and a group of local curriculum experts. Overall, these modules are developed to supplement the national curriculum and support learning in out-of-school settings.

Table 1. Modules and content of the intervention

Module	No of lessons	Contents
Literacy (English)	22	Sentence structure, vocabulary, story.
Literacy (Bangla)	8	Vocabulary, synonyms, antonyms.
Numeracy	30	Counting, addition, subtraction, comparison, equation, forms of number, sorting.
Noncognitive skills	15	Leadership, qualities of a leader, active listening, communication & presenting, planning, bragging vs. humility, patience, empathy, sympathy & compassion, perseverance.

These audio lessons are basically a pre-recorded conversation among four characters, two teachers and two students. During the conversation, students do some activities as per instructions of teachers such as clapping, standing up, counting using countable, making plans etc. The teachers give regular pauses, cues, play music and songs during recorded lessons for listeners to complete similar tasks with their parents. It is the parent's responsibility to check whether their child follows the instructions or not. These instructions are easy to follow for any adult and do not require a high level of literacy and numeracy skills. Besides, we offer a noncognitive skills module that provides scope to engage in various non-academic activities with the parent. These actives cover leadership, communication, planning, patience, empathy, sympathy, compassion, and perseverance. We are interested in examining whether these discussions and related activities affect the noncognitive abilities such as impulsivity, grit, growth mindset, empathy, leadership, planning, communication of children.

We implement this intervention using a multi-arm RCT design. We are interested in evaluating the effect of the intervention on the cognitive as well as the noncognitive domain of

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[1] Literacy and numeracy lessons are developed based on the lessons of 'Rising on Air' program and noncognitive skills module is developed based on 'LEAD Learning' program. These lessons are completely rewritten and contextualized.

participants separately. In the T1: *Standard* group, we offer a literacy and numeracy module, and in the T2: *Extended* group, we include 'noncognitive skill' module with literacy and numeracy. These treatment arms are exhibited in Figure 2. This educational intervention will last for 15 weeks.

Figure 1: Intervention Timeline

			Intervention		
Preparation	Baseline	Training	starts	end	Endline
↓	↓	↓	↓	↓	↓
Mar to May 21 Content design; Recordings; IVR flow design & optimization; field test.	*May 21* Baseline Survey	*Jun 21* Randomization; mothers' training.	*Jun 21* 15-week	*Oct 21* intervention period	*Nov 21* Children's assessment test; children's survey; parental survey

We allocate 4 lessons (2 literacy and 2 numeracy) per week for T1: *Standard* group; and 5 lessons (2 literacy, 2 numeracy and 1 noncognitive skill) per week for T2: *Extended* group. However, parents can choose and access any lesson at any week during the teaching period for their child. We do not mandate a fixed sequence in our curriculum i.e., if any learner finds any lesson easy, they can skip the lesson and listen to the next one. There are two reasons for this design. First, we target students of three different grades i.e., grades 2, 3 and 4. Second, even in the same grade, students' abilities vary significantly (Islam and Ruthbah, 2020). Usually, students can learn better if they are provided with the educational content that matches their capacity (Banerjee et al., 2007). By offering content of different grades to all children, we are in effect offering a menu of choices so that children can take advantage of learning more or catching up with the learning gap when they are behind their grade/age level. Thus, the program has elements of the 'learning at the right level' (LARL) approach, just like the Teaching at the Right Level approach (Banerjee et al., 2016). We believe this flexibility will be more helpful for children, particularly those who are at the bottom of the test-score distribution.

Our field partner, GDRI, worked in 223 villages in 5 sub-districts from 2 districts in the South-West region of Bangladesh in a previous project. From this list, we randomly select 90 villages with mobile phone numbers for about 3000 households. We were able to reach and complete the baseline survey of 2,400 children (2,387 households). Others did not respond, or the phone was not active, invalid, or switched off or did not show interest in this intervention. We then randomly select about 16-22 children[2] from each of these 90 villages and randomly divide the 90 villages into three treatment arms. Our final sample size is 1741 children from 1732 households. See Figure 2 for the sample size in the various treatment arms.

T1: Standard – Children of this group receive 60 lessons over 15 weeks. They listen and interact as per the instruction. The 'Special Helper' helps them to follow these instructions and takes part in various activities. Two modules are covered in this treatment arm: Numeracy and

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[2] There are four villages with less than 16 children, 10 children each in 2 villages, 11 children in 1 village and 13 children in 1 village. We choose the sample size cap of 22 children per village to match the budgetary allocation. Our power analysis suggests that a sample consisting of 10 children from each village is required to detect 0.30SD treatment effect with 80% power at 5% level of significance.

Literacy. The content of these modules and delivery method is explained above. After each lesson, a quiz is played to the listener, and the answer is recorded in the IVR flow. 15 listeners are randomly selected every week from the pool of listeners who had given correct answers during that week to give a small amount of money (US$3) via mobile financial services (MFS) as a prize. The reason for this quiz is to motivate parents to complete the lesson as quizzes are not accessible otherwise.

Figure 2. The RCT Design
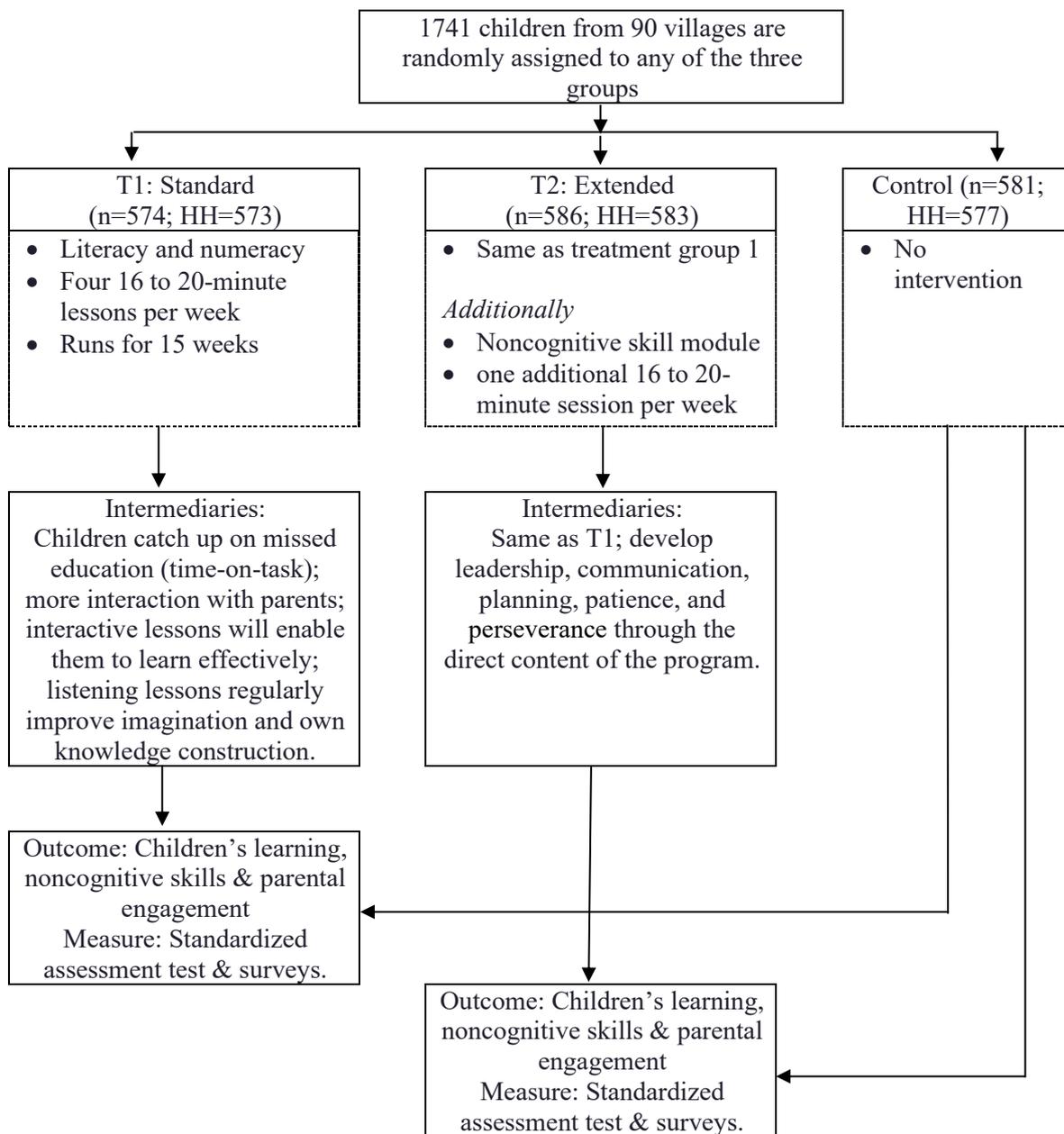
T2: Extended - T1+Noncognitive – In addition to the T1 group, the T2 group is receiving an additional module that contains various noncognitive skills training. We particularly focus on leadership, communication, planning, patience, empathy, sympathy, compassion, and perseverance. These topics are introduced to children and explained how they can gain these qualities with various examples and exercises. Listeners of this group also participate in the

post-lesson quiz and 15 of them are randomly selected for a lottery prize. Note that the noncognitive skill module does not have a quiz component.

T3: Control – There is no intervention under this group.

2.2 Data

2.2.1 Surveys and Assessment

Children and their parents were surveyed in 2019 as part of an early childhood intervention conducted by GDRI. These surveys collected information about demographics, income, employment status, household asset composition, livelihood, and parental involvement, etc. As part of the evaluation of the previous project, these children were assessed in 2019. The assessment tests comprised various domains, such as language, literacy, numeracy, fine & gross motor skills, problem-solving, personal-social domain, working memory, self-regulation. Besides, for this project, we conducted a face-to-face survey in May and June 2021 to update previously collected information and to collect information about children's educational situation and household's private educational investment during the COVID-19 pandemic. We use this extensive set of rich data to check whether the characteristics of treatment and control groups are balanced.

During the intervention, we collect IVR-flow usage data i.e., duration of lesson-play by each participant, access time and date, frequency etc. from the server. These will be used mainly to understand the channels and difficulties parents faced in using the technology and to explore heterogeneity.

Because of the COVID-19 related mobility restrictions during the project, we hired a project assistant in each village as our local contact. These project assistants previously worked in these villages for GDRI to conduct surveys and assessments of these children, and they are familiar with the parents and children. They were hired to contact parents and children in the same village if there is any difficulty or problem in accessing our lessons via our program numbers. We deliberately keep their role as minimum as possible. We also collect some users' usage information from these village informants such as which mobile number household's use in case of the number change, the number of lessons completed by each child. We will use this data to combine the server usage data with the household-level data.

The endline data will be collected in November 2021 (see Figure 1). We will assess children's cognitive ability and carry out a parental survey in the endline. The endline assessment test will comprise literacy, numeracy, and general knowledge questions. This test will be conducted in a one-on-one format by maintaining the COVID-19 protocol. Table A1 in the appendix exhibits sample questions of an assessment test. Besides assessment, we will administer few psychometric scales to understand the effect of the intervention in noncognitive domains. These scales are explained in Section 2.2.2. Field staff will be briefed by a psychologist to conduct these surveys. We will also ask various questions to the mother related to the child to understand the treatment effect on the development of various soft skills, such as creativity, motivation, leadership, communication, and planning.

Enumerators will survey with the mothers to collect information about parental involvement and engagement in children's education, parent-child interactions, parental inputs, children's time use, general program assessment etc. through an in-depth face-to-face survey with structured questionnaires.

2.2.2 Outcome Variables

There are four primary outcomes and three secondary outcomes.

Primary outcome variables (PO)

1. **Children's cognitive ability:** Children's cognitive ability will be measured using a standard assessment test based on the national curriculum of Bangladesh. The test totals 100 points which are divided into literacy, numeracy, and general knowledge. The answers are in binary form. Grade-specific sample questions are provided in the Table A1 of the Appendix. To examine the effect of treatment (IRI lessons) on cognitive ability, we will construct two outcome variables: test score (continuous; $Y_i^{cog} \in [0,100]$), and standardized test score.

2. **Children's noncognitive skills:** We will measure self-control of the children by using the Impulsivity Scale for Children (ISC), an 8-item survey that gives domain-specific students' impulsivity, defined as the "inability to regulate behavior, attention, and emotions in the service of valued goals" (Tsukayama et al., 2013). We will construct 3 outcome variables from this scale: overall impulsivity score (continuous; $Y_i^{ISC} = \frac{\sum_{q=1}^{q=8} ISC_q}{8} \in [1,5]$), schoolwork impulsivity score (continuous; $Y_i^{sch} = \frac{\sum_{q=1}^{q=4} ISC_q}{4} \in [1,5]$), and interpersonal impulsivity score (continuous; $Y_i^{per} = \frac{\sum_{q=1}^{q=4} ISC_q}{4} \in [1,5]$). We will also measure grit of the participants using an 8-item grit scale (Duckworth and Quinn, 2009). This scale measures perseverance – grit – as an individual difference score. We will construct an outcome variable from this scale: overall grit scale (continuous; $Y_i^{grit} = \frac{\sum_{q=1}^{q=8} GRIT_q}{8} \in [1,5]$). Furthermore, we will measure the extent to which participating children view intelligence as a fixed behavioral trait rather than a feature that can be improved with effort using 3-item growth mindset scale (Dweck et al., 1995, Dweck, 2013). We will construct an outcome variable from this scale: growth mindset scale (continuous; $Y_i^{gms} = \frac{\sum_{q=1}^{q=3} GMS_q}{3} \in [1,6]$). Finally, we will measure impact of the intervention on prosocial attitude of the children. We expect that beneficiaries of a philanthropic program will show more prosociality compared to the children from control group. We will use the Empathy Questionnaire for Children and Adolescents (EmQue-CA) that is an 18-item self-report questionnaire to examine the level of empathy in three domains: affective empathy, cognitive empathy, and prosocial Motivation (Overgaauw et al., 2017). We will construct 3 outcome variables from this scale: affective empathy (continuous; $Y_i^{EmA} = \frac{\sum_{q=1}^{q=7} EmQue_q}{7} \in [0,2]$), cognitive empathy

(continuous; $Y_i^{EmC} = \frac{\sum_{q=1}^{q=5} EmQue_q}{5} \in [0,2]$), and prosocial motivation (continuous; $Y_i^{EmP} = \frac{\sum_{q=1}^{q=6} EmQue_q}{6} \in [0,2]$). Items of these three scales are listed in Table A2.

3. **Renzulli Scale (partial):** We will use Scales for Rating the Behavioral Characteristics of Superior Students by Renzulli et al. (2002). This scale has 14 subscales. We will use leadership, communication, and planning subscales as our modules focus on these dimensions (see Table 1). We will construct three outcome variables for characteristics: leadership (continuous; $Y_i^{lead} \in [7,42]$), communication (continuous; $Y_i^{com} \in [4,24]$), and planning (continuous; $Y_i^{plan} \in [15,90]$). Items of these three characteristics are listed in Table A3.

4. **Strengths and Difficulties Questionnaire (SDQ):** We will use the Strengths and Difficulties Questionnaire (SDQ) by Goodman (1997). This scale has 25 items divided into 5 subscales such as emotional symptoms, conduct problem, hyperactivity, peer problem, and prosocial scale. These questions will be answered by mothers. We will construct five outcome variables for characteristics: emotional symptoms scale (continuous; $Y_i^{ess} \in [0,10]$), conduct problem scale (continuous; $Y_i^{cps} \in [0,10]$), hyperactivity scale (continuous; $Y_i^{hs} \in [0,10]$), peer problem scale (continuous; $Y_i^{pps} \in [0,10]$), and prosocial scale (continuous; $Y_i^{ps} \in [0,10]$). Items of this scale are listed in Table A4. Main motivation of using this scale is to check whether current school closure triggers any fatigue, abnormality or conduct problem among the students. Furthermore, we want to investigate whether participation in this program reduces such problems by giving additional activities to do.

Secondary outcome variables (SO)

1. **Student time spent on homework or homeschooling:** Students' time investment because of the intervention will be measured by asking the following questions to the mother:
   a. How much time (hours) in various academic activities (i.e., writing, reading, storytelling, mathematics, etc.) does your child spend each week? Total hours spent in various academic activities will be used as an outcome variable (continuous; $Y_i^{ST} \in [0, Y_{max}^{ST}]$) for student time investment in academic activities.
   b. To what extent does your child provide time in academic activities (5-point Likert-scale response; 'none' to 'a great deal'; $Y_i^{STC} \in \{1..5\}$) The response will be re-coded as a dummy variable.

2. **Mother's Time Investment in Children's Education:** Parental involvement in children's educational activities will be measured by asking the following questions to the mother:
   a. How much time (hours) do you give to your child each week in various academic activities (i.e., writing, reading, storytelling, mathematics, etc.)? Total hours spent in various academic activities will be used as an outcome variable (continuous; $Y_i^{PI} \in [0, Y_{max}^{PI}]$) for parental involvement in children's academic activities.

b. To what extent do you provide academic support to your child (5-point Likert-scale response; 'none' to 'a great deal'; $Y_i^{PIC} \in \{1..5\}$) The response will be re-coded as a dummy variable.

3. **Parenting Style and Dimension:** We will also measure parenting style and dimension using the Bangla version of the Parenting Style and Dimension Questionnaire (PSDQ) by Robinson et al. (1995), which is translated by Yasir Arafat (2020). We will construct three outcome variables for parenting style: authoritative domain (continuous; $Y_i^{A1} \in [20,100]$), authoritarian domain (continuous; $Y_i^{A2} \in [9,45]$), and permissive domain (continuous; $Y_i^{A3} \in [6,30]$). Items of these three characteristics are listed in Table A5.

2.3 Hypotheses

The intervention is hypothesized to:

1. Improve the cognitive ability of the children. *(PO1)*
2. Improve the noncognitive skills of the children such as self-control, grit, and growth mindset. *(PO2)*
3. Improve leadership, communication, and planning skills of the children. *(PO3)*
4. Reduces the behavioral impact of school closure i.e., fatigue, abnormality or conduct problem among the students. *(PO4)*
5. Increase students' effort in educational activities. *(SO1)*
6. Increase parental involvement in children's educational activities. *(SO2)*
7. Change the parenting style. *(SO3)*

2.3.1 Multiple Hypotheses Testing

As we consider a range of outcomes for parents and children, we will perform tests of multiple hypotheses to correct p-values using the Westfall-Young (WY) adjustment (Westfall and Young, 1993), which accounts for the correlations across outcome variables using sample bootstrapping (e.g., using 1,000 and 5,000 as parameters for replications and robustness respectively).

3 Empirical Analyses

3.1 Attrition and Sample Balance – Pre-Intervention

Due to the current COVID-19 crisis, there is potentially a high degree of attrition from the program. We plan to address potential attrition in two ways. First, we will check whether attrition and treatment status are systematically related or not through tests of differential attrition.[3] Second, we will use inverse-probability-of-attrition weighting (IPAWs) and Lee bounds to address the attrition if there is any (Lee, 2009).

Another related issue is partial completion, i.e., some parent-child duos may only complete some of the weeks/lessons of this educational intervention. We will examine the

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[3] Differential attrition refers to the systematic difference in the rate of attrition across the treatment and control groups. Whereas, selective attrition occurs when the mean of baseline test scores differs, conditional on treatment status.

number of sessions participants attended and identify participants who participate partially. This will potentially give us non-experimental but crucial evidence to understand the determinants of program completion. Using information about their program participation each week, we can identify parents, children, and their characteristics likely to benefit most from such intervention, and others who might need additional encouragement to attend and benefit from this kind of program.

Table 2 depicts balance on several key socio-economic characteristics and children's assessment scores. These characteristics are balanced across the treatment and control groups.

Table 2. Balance Table

	Standard	Extended	Control	Total	F-test
Age (as of 01/01/2021)	7.383	7.388	7.378	7.383	0.8510
	(0.0357)	(0.0348)	(0.0347)	(0.016	
Boy	0.491	0.486	0.478	0.485	0.7036
	(0.0225)	(0.0228)	(0.0218)	(0.012	
Baseline literacy score	17.04	16.63	16.86	16.841	0.9417
	(0.328)	(0.233)	(0.348)	(0.102	
Baseline numeracy score	14.86	14.66	14.84	14.786	0.6982
	(0.211)	(0.173)	(0.170)	(0.073)	
Access to private tuition	0.512	0.580	0.565	0.553	0.6968
	(0.0328)	(0.0373)	(0.0398)	(0.012)	
Father's Education (in years of schooling)	6.308	5.847	5.752	5.967	0.2721
	(0.250)	(0.221)	(0.243)	(0.010)	
Mother's education (in years of schooling)	7.298	6.957	7.007	7.086	0.6225
	(0.246)	(0.182)	(0.191)	(0.081)	
Household member	4.758	4.761	4.892	4.80	0.1907
	(0.107)	(0.0709)	(0.0768)	(0.035)	
Family income (in BDT)	11,006	10,900	11,190	11032	0.6316
	(305.1)	(350.0)	(433.5)	(130.9)	
Homestead land (in decimal)	9.294	9.564	11.26	10.04	0.1401
	(0.604)	(0.860)	(1.110)	(0.438)	
Observation	574	586	577	1741	
Villages	30	30	30	90	

Note:
a. This table reports the background characteristics of the participants of different groups and for all participants. The rightmost column reported the p-value from the F-test of Joint significance.
b. Standard errors in parentheses.

3.2 Outcomes

To test our hypotheses mentioned in section 2.3, we estimate the following OLS regression specification:

$$[1] \quad Y_i = \alpha + \beta_1 T1_i + \beta_2 T2_i + X_i'\theta + \varepsilon_i$$

where Y_i is the outcome of an individual (child or parent) from household i measured at the endline; $T1_i$ and $T2_i$ are the treatment indicators, and X is a vector of individual and household-specific characteristics. We list controls in the next section. We will cluster the standard errors at the village level. In equation 1, β_1 and β_2 provide estimates for the intent to treat (ITT) effect – an average of the causal effects of receiving treatment on the outcome variables.

Besides ITT, we would also estimate treatment on the treated (TOT) effect, which is straightforward to calculate in this case i.e., $\beta/\gamma T$. Here, γT is the intervention completion rate. We use randomization offer as an instrument of the take-up to measure the ToT effect. Since the number of sessions, a parent listen could be endogenous conditional on participation in the program we will provide non-experimental evidence of the association between participation intensity and the outcome variables (test scores).

Additionally, we would estimate treatment effects using the intensity of the participation (number of sessions attended).

<div align="center">Control variables</div>

- Age of the children (in years)
- Gender
- Grade of study
- Baseline literacy and numeracy score
- Household monthly income
- Household assets (homestead and farmland)
- Parents' education (number of years of education)
- Number of household members (total members and number of siblings)
- Other demographic characteristics
- Educational input during this current school closure such as private tuition, extra time by siblings or other household members etc.
- **Social desirability score:** As many of our outcome variables rely on surveys, social desirability bias may arise. More specifically, the experimenter demand effect can lead to over or underestimation of treatment effect. We will survey the parents using the short-form Crowne-Marlowe module (Crowne and Marlowe, 1960, Reynolds, 1982) and children using the Children's Social Desirability (CSD-S) scale (Miller et al., 2015) to measure social desirability bias. Table A6 exhibits questions of these two scales.

3.3 Heterogeneity Analysis

We will also conduct a heterogeneity analysis based on the gender of the children. To explore heterogeneity, we would estimate the following interaction model:

$$[3] \quad Y_i = \alpha + \beta_1 T1_i + \beta_2 T2_i + \beta_3 H_i + \beta_4 (T \times H)_i + X_i'\theta + \varepsilon_i$$

where H_i is alternatively i) gender of the children, ii) parental education, iii) HH income, iv) baseline literacy and numeracy score, v) access to private educational support i.e., tuition and vi) social desirability score. We will also explore heterogeneity based on other household characteristics using the machine learning approach explained in the next section.

3.3.1 Heterogeneity Analysis Using Machine Learning

The traditional approach of estimating heterogeneous effects with the interaction between treatment and different variables of interest has some limitations. Too many variables may

bring computational challenges and increase the risk of over-fitting. On the contrary, restricting to a particular subset of variables to estimate heterogeneous effects may lead to arbitrary decision making and the loss of information about potential heterogeneity (Carlana and La Ferrara, 2021). To overcome these challenges, we estimate the heterogeneous treatment effect using an honest casual forest algorithm (Wager and Athey, 2018). In particular, we follow the estimation procedure of Davis and Heller (2017). According to this approach, we split the sample into two subsamples. One sub-sample, the training sample, is used to implement the causal forest algorithm. The other subsample, the test sample, is used to compute average treatment effects. We follow this procedure for both treatment arms.

3.4 Analysis of the Channels of Treatment Effect

We would also seek to identify possible channels by which this IRI-based educational intervention led to improvement in the children's outcome. In the post-intervention period, we will estimate the children's outcome by controlling study time and effort by the students, private tuition, parental knowledge, and perception about the program to understand how much improvement in children's outcomes are likely due to these intermediaries or how much due to other things (like supervision, guidance etc. that might not directly relate to the intermediaries). Though these estimates are not causal, they provide some guidance to policymakers whether to focus more on parental knowledge or not or provide input directly to children.
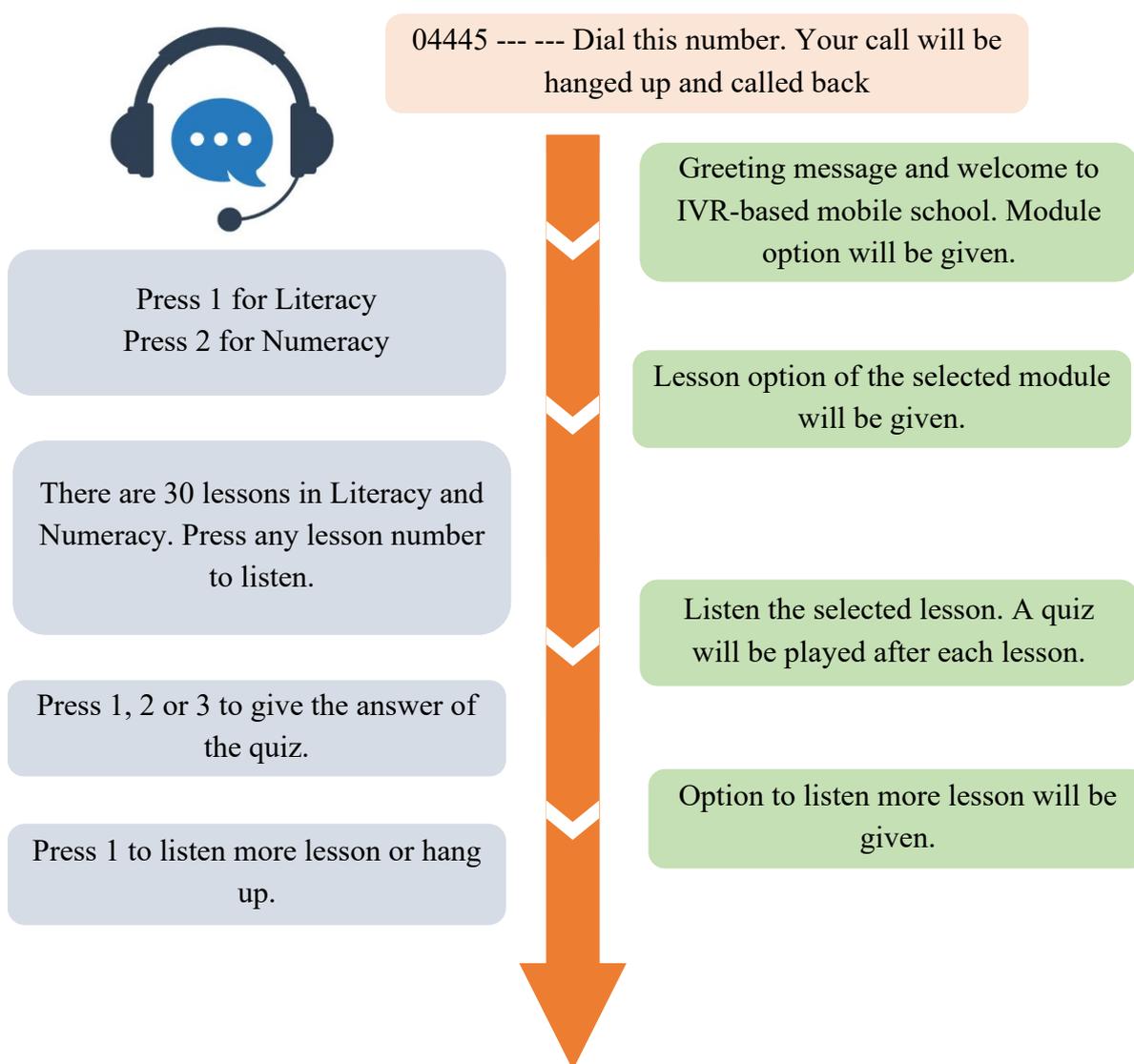
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Appendix A

Figure A1. IVR flow diagram of Treatment 1 – Standard [Translation from Bangla Flyer]

04445 --- --- Dial this number. Your call will be hanged up and called back

Greeting message and welcome to IVR-based mobile school. Module option will be given.

Press 1 for Literacy
Press 2 for Numeracy

Lesson option of the selected module will be given.

There are 30 lessons in Literacy and Numeracy. Press any lesson number to listen.

Listen the selected lesson. A quiz will be played after each lesson.

Press 1, 2 or 3 to give the answer of the quiz.

Option to listen more lesson will be given.

Press 1 to listen more lesson or hang up.

General guideline:
1. Put your phone in to loud-speaker mood during the lesson play and listen with your child.
2. Every week a randomly few will get prizes based on their correct answers of quizzes.
3. If you receive another call during the lesson play, you have call again and navigate to lesson you were listening.

Figure A2. IVR flow diagram of Treatment 2 – Extended [Translation from Bangla Flyer]
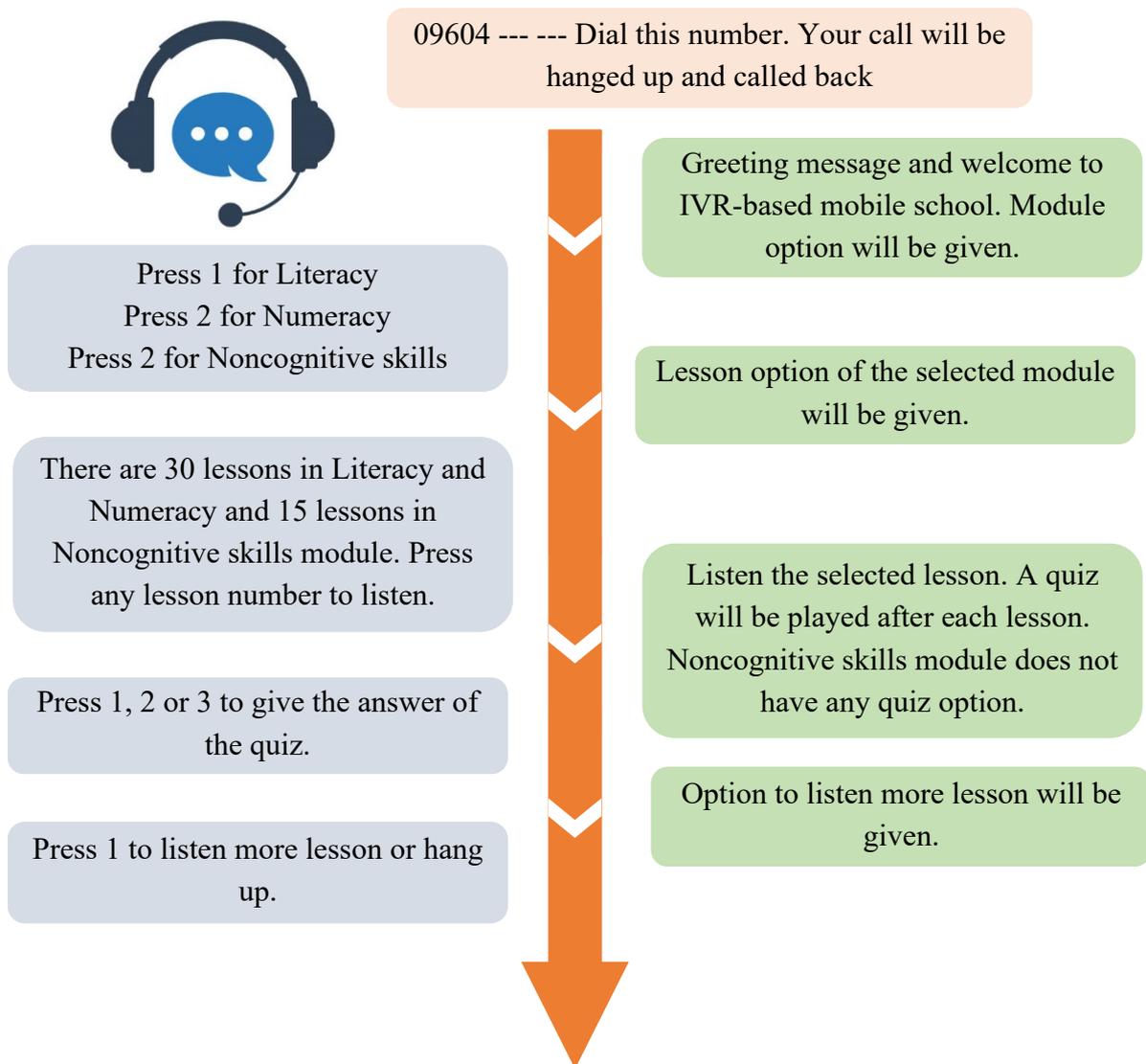
09604 --- --- Dial this number. Your call will be hanged up and called back

Greeting message and welcome to IVR-based mobile school. Module option will be given.

Press 1 for Literacy
Press 2 for Numeracy
Press 2 for Noncognitive skills

Lesson option of the selected module will be given.

There are 30 lessons in Literacy and Numeracy and 15 lessons in Noncognitive skills module. Press any lesson number to listen.

Listen the selected lesson. A quiz will be played after each lesson. Noncognitive skills module does not have any quiz option.

Press 1, 2 or 3 to give the answer of the quiz.

Option to listen more lesson will be given.

Press 1 to listen more lesson or hang up.

General guideline:
1. Put your phone in to loud-speaker mood during the lesson play and listen with your child.
2. Every week a randomly few will get prizes based on their correct answers of quizzes.
3. If you receive another call during the lesson play, you have call again and navigate to lesson you were listening.

Table A1. Children's assessment test of different grades

Subject	No	Level 1	Level 2	Level 3	Marks
Bangla Literacy	1.	Give an example of one Bangla vowel letter.	Make two words using the Bangla letter ----.	Make one word and a sentence from that word using the Bangla letter (---).	5
	2.	Which two letters come after letters ---- & ----.	Give an example of a word written with joint letters.	What is the antonym of the Bangla word (freedom)?	5
	3.	Make a word with Bangla letter -----.	What is the spelling of the word (Sundarbans)?	What is the spelling of the word (freedom fighter)?	5
	4.	What is the English of ------ (common flower name)?	What is the antonym of the Bangla word (high)?	What is the meaning of the Bangla word (----)?	5
General Knowledge	5.	How many days there are in a week?	Give an example of five flowers.	On which date of 1952, there was a march for the Bangla language?	5
	6.	What are the days come after Saturday?	What is the first month of Bangla year?	What is victory day in Bangladesh?	5
	7.	Give an example of three flowers.	Which season is best for homemade cakes?	Mostafa Kamal is an ----.	5
	8.	What is the national animal of Bangladesh?	What was the pet name of the national poet of Bangladesh?	How many days there are in the month 'March'?	5
English Literacy	9.	Make a word with 'C'.	Make a word with 'M'.	Make two words with 'C'.	6
	10.	Answer this English question: What is your name?	Answer this English question: How old are you?	Answer this English question: What month is it now?	6
	11.	Tell the English of Bangla word – (Hand).	Tell the English of Bangla word – (Window).	Tell the English of Bangla word – (Farmer).	4
	12.	Tell the English of Bangla word – (Book).	Tell the English of Bangla word – (Rose).	Tell the English of Bangla word – (Umbrella).	4
	13.	Tell the English of Bangla word – (Dog).	Tell the English of Bangla word – (Breakfast).	Tell the English of Bangla word – (Flag).	4
	14.	Spell your name in English.	Spell the English word 'Mother'.	Spell 'English Teacher' in English.	6
Mathematics	15.	Which number comes after 6? Does it even or odd?	Name the even numbers in between 1 and 10.	Which number is bigger in 525 and 495?	6
	16.	What is the sum of 3 and 4?	Whether the sum of 3 and 4 is an even or odd number?	There are 6 notes of 20 taka. How much money is there?	6
	17.	If we deduct 3 from 8, what remains?	In a class, there were 16 students. The teacher sends 5 of them for gardening. How many students are left in the classroom?	Whether the sum of 13 and 11 is an even or odd number?	6
	18.	How many minutes in 60 seconds?	How many sides a triangle has?	How many sides a rectangle has?	6
	19.	6+0 equals to what?	There are three fruits on a plate. How many fruits there are in 4 plates?	The price of 5 eggs is BDT 30. How much does it cost to buy 2 eggs?	6

Table A2. Children's noncognitive assessment surveys

Scale	No	Questions	Answer
8-item Impulsivity Scale for Children	1.	I forgot something I needed for class.	(1) Almost never
	2.	I interrupted other students while they were talking.	(2) About once a month
	3.	I said something rude.	(3) About 2-3 times a month
	4.	I couldn't find something because my desk, locker, or bedroom was messy.	(4) About once a week
	5.	I lost my temper at home or at school.	(5) At least once a day
	6.	I did not remember what my teacher told me to do.	
	7.	My mind wandered when I should have been listening.	
	8.	I talked back to my teacher or parent when I was upset.	
8-item Grit Scale	1.	**New ideas and projects sometimes distract me from previous ones. (R)**	(1) Very much like me
	2.	New ideas and projects sometimes distract me from previous ones.	(2) Mostly like me
	3.	**I have been obsessed with a certain idea or project for a short time but later lost interest. (R)**	(3) Somewhat like me
	4.	I am a hard worker.	(4) Not much like me
	5.	**I often set a goal but later choose to pursue a different one. (R)**	(5) Not like me at all
	6.	**I have difficulty maintaining my focus on projects that take more than a few months to complete. (R)**	
	7.	I finish whatever I begin.	
	8.	I am diligent.	
Growth Mindset Scale	1.	You have a certain amount of intelligence, and you can't really do much to change it.	(1) Strongly agree
	2.	Your intelligence is something about you that you can't change very much.	(2) Agree
	3.	You can learn new things, but you can't really change your basic intelligence.	(3) Mostly agree
			(4) Mostly disagree
			(5) Disagree
			(6) Strongly disagree
Empathy Questionnaire for Children and Adolescents (EmQue-CA)	1.	If my mother is happy, I also feel happy.	(1) Not true
	2.	I understand that a friend is ashamed when he/she has done something wrong.	(2) Sometimes true
	3.	If a friend is sad, I like to comfort him.	(3) often true
	4.	I feel awful when two people quarrel.	
	5.	When a friend is angry, I tend to know why.	
	6.	I would like to help when a friend gets angry.	
	7.	If a friend is sad, I also feel sad.	
	8.	I understand that a friend is proud when he/she has done something good.	
	9.	If a friend has an argument, I try to help.	
	10.	If a friend is laughing, I also laugh.	
	11.	If a friend is sad, I understand mostly why.	
	12.	I want everyone to feel good.	
	13.	When a friend cries, I cry myself.	
	14.	If a friend cries, I often understand what has happened.	
	15.	If a friend is sad, I want to do something to make it better.	
	16.	If someone in my family is sad, I feel really bad.	
	17.	I enjoy giving a friend a gift.	
	18.	When a friend is upset, I feel upset too.	

NB. Bold items indicate reverse scoring

Table A3. Renzulli scale

Scale	No	Questions	Answer
		[Every statement will start with] My child demonstrates . . .	
7-item Leadership Characteristics	1.	responsible behavior, can be counted on to follow through on activities/projects.	(1) Never (2) Very rarely (3) Rarely (4) Occasionally (5) Frequently (6) Always
	2.	a tendency to be respected by classmates.	
	3.	the ability to articulate ideas and communicate well with others.	
	4.	self-confidence when interacting with age peers.	
	5.	the ability to organize and bring structure to things, people, and situations.	
	6.	cooperative behavior when working with others.	
	7.	a tendency to direct an activity when he or she is involved with others.	
4-item Communication Characteristics	1.	uses voice expressively to convey or enhance meaning.	(1) Never (2) Very rarely (3) Rarely (4) Occasionally (5) Frequently (6) Always
	2.	conveys information nonverbally through gestures, facial expressions, and "body language."	
	3.	is an interesting storyteller.	
	4.	uses colorful and imaginative figures of speech such as puns and analogies.	
15-item Planning Characteristics	1.	determines what information or resources are necessary for accomplishing a task.	(1) Never (2) Very rarely (3) Rarely (4) Occasionally (5) Frequently (6) Always
	2.	grasps the relationship of individual steps to a whole process.	
	3.	allows time to execute all steps involved in a process.	
	4.	foresees consequences or effects of action.	
	5.	organizes his or her work well.	
	6.	takes into account the details necessary to accomplish a goal.	
	7.	is good at games of strategy where it is necessary to anticipate several moves ahead.	
	8.	recognizes the various alternative methods for accomplishing a goal.	
	9.	can pinpoint where areas of difficulty might arise in a procedure or activity.	
	10.	arranges steps of a project in a sensible order or time sequence.	
	11.	is good at breaking down an activity into step-by-step procedures.	
	12.	establishes priorities when organizing activities.	
	13.	shows awareness of limitations relating to time, space, materials, and abilities when working on group or individual projects.	
	14.	can provide details that contribute to the development of a plan or procedure.	
	15.	sees alternative ways to distribute work or assign people to accomplish a task.	

Table A4. Strengths and Difficulties Questionnaire (SDQ)

No	Questions	Subscale	Answer
	Every statement will start with] My child …		
1.	Considerate of other people's feelings	Prosocial	
2.	Restless, overactive, cannot stay still for long	Hyperactivity	
3.	Often complains of headaches, stomach-aches, or sickness	Emotional Symptoms	
4.	Shares readily with other children, for example toys, treats, pencils	Prosocial	
5.	Often loses temper	Conduct Problem	
6.	Rather solitary, prefers to play alone	Peer Problem	
7.	**Generally, well behaved, usually does what adults request (R)**	Conduct Problem	
8.	Many worries or often seems worried	Emotional Symptoms	
9.	Helpful if someone is hurt, upset, or feeling ill	Prosocial	
10.	Constantly fidgeting or squirming	Hyperactivity	
11.	**Has at least one good friend (R)**	Peer Problem	1) Not true
12.	Often fights with other children or bullies them	Conduct Problem	2) Somewhat true
13.	Often unhappy, depressed, or tearful	Emotional Symptoms	
14.	**Generally liked by other children (R)**	Peer Problem	3) Certainly true
15.	Easily distracted, concentration wanders	Hyperactivity	
16.	Nervous or clingy in new situations, easily loses confidence	Emotional Symptoms	
17.	Kind to younger children	Prosocial	
18.	Often lies or cheats	Conduct Problem	
19.	Picked on or bullied by other children	Peer Problem	
20.	Often volunteers to help others (parents, teachers, other children)	Prosocial	
21.	**Thinks things out before acting (R)**	Hyperactivity	
22.	Steals from home, school or elsewhere	Conduct Problem	
23.	Gets along better with adults than with other children	Peer Problem	
24.	Many fears, easily scared	Emotional Symptoms	
25.	**Good attention span, sees chores or homework through to the end (R)**	Hyperactivity	

NB. Bold items indicate reverse scoring

Table A5. Parenting Style and Dimension Questionnaire (PSDQ) - Bangla

Scale	No	Questions	Answer
		Make two ratings for each item; (1) rate how often your spouse exhibits this behavior with your child and (2) how often you exhibit this behavior with your child.	
20-item authoritative Domain	1.	[He encourages] [I encourage] our child to talk about the child's troubles.	Spouse exhibits behavior: (1) Never (2) Once in a while (3) About half of the time (4) Very often (5) Always
	2.	[He knows] [I know] the names of our child's friends.	
	3.	[He gives praise] [I give praise] when our child is good.	
	4.	[He shows] [I show] sympathy when our child is hurt or frustrated.	
	5.	[He is] [I am] easy going and relaxed with our child.	
	6.	[He tells] [I tell] child our expectations regarding behavior before the child engages in an activity.	
	7.	[He shows] [I show] patience with our child.	
	8.	[He is] [I am] responsive to our child's feelings or needs.	
	9.	[He gives] [I give] our child reasons why rules should be obeyed.	
	10.	[He tells] [I tell] our child that we appreciate what the child tries or accomplishes.	
	11.	[He takes] [I take] our child's desires into account before asking the child to do something.	
	12.	[He is] [I am] aware of problems or concerns about our child in school	
	13.	[He expresses] [I express] affection by hugging, kissing, and holding our child.	
	14.	[He talks it over and reasons] [I talk it over and reason] with our child when the child misbehaves.	
	15.	[He has] [I have] warm and intimate times together with our child.	
	16.	[He encourages] [I encourage] our child to freely express (himself)(herself) even when disagreeing with parents.	
	17.	[He explains] [I explain] to our child how we feel about the child's good and bad behavior.	I exhibit this behavior: (1) Never (2) Once in a while (3) About half of the time (4) Very often (5) Always
	18.	[He takes] [I take] into account our child's preferences in making plans for the family.	
	19.	[He explains] [I explain] the consequences of the child's behavior.	
	20.	[He emphasizes] [I emphasize] the reasons for rules.	
20-item authoritarian domain	1.	[He guides] [I guide] our child by punishment more than by reason.	
	2.	[He slaps] [I slap] our child when the child misbehaves	
	3.	[He punishes] [I punish] by taking privileges away from our child with little if any explanations.	
	4.	[He yells or shouts] [I yell or shout] when our child misbehaves.	
	5.	[He scolds and criticizes] [I scold and criticize] to make our child improve.	
	6.	[He appears] [I appear] to be more concerned with own feelings than with our child's feelings.	
	7.	[He disagrees] [I disagree] with our child.	
	8.	[He uses] [I use] threats as punishment with little or no justification.	
	9.	[He demands] [I demand] that our child does/do things	
9-item permissive domain	1.	[He finds] [I find] it difficult to discipline our child.	
	2.	[He spoils] [I spoil] our child.	
	3.	[He is] [I am] afraid that disciplining our child for misbehavior will cause the child to not like his/her parents.	
	4.	[He ignores] [I ignore] our child's misbehavior.	
	5.	[He gives] [I give] into our child when the child causes a commotion about something.	
	6.	[He allows] [I allow] our child to interrupt others.	

Note: Validated Bangla version will be used, these questions are taken from English version.

Table A6. Social Desirability Scales

Scale	No	Questions	Desired answer	Answer
Marlowe-Crowne Scale (Reynolds' Form C)	1.	It is sometimes hard for me to go on with my work if I am not encouraged.	False	1) True 2) False
	2.	I sometimes feel resentful when I don't get my way.	False	
	3.	On a few occasions, I have given up doing something because I thought too little of my ability.	False	
	4.	There have been times when I felt like rebelling against people in authority even though I knew they were right.	False	
	5.	No matter who I'm talking to, I'm always a good listener.	True	
	6.	There have been occasions when I took advantage of someone.	False	
	7.	I'm always willing to admit it when I make a mistake.	True	
	8.	I sometimes try to get even rather than forgive and forget.	False	
	9.	I am always courteous, even to people who are disagreeable.	True	
	10.	I have never been irked when people expressed ideas very different from my own.	True	
	11.	There have been times when I was quite jealous of the good fortune of others.	False	
	12.	I am sometimes irritated by people who ask favors of me.	False	
	13.	I have never deliberately said something that hurt someone's feelings.	True	
Children's Social Desirability Short (CSD-S) scale	1.	Have you ever felt like saying unkind things to a person?	No	1) Yes 2) No
	2.	Are you always careful about keeping your clothing neat and your room picked up?	Yes	
	3.	Do you sometimes feel like staying home from school even if you are not sick?	No	
	4.	Do you ever say anything that makes somebody else feel bad?	No	
	5.	Are you always polite, even to people who are not very nice?	Yes	
	6.	Sometimes, do you do things you've been told not to do?	No	
	7.	Do you always listen to your parents?	Yes	
	8.	Do you sometimes wish you could just play around instead of having to go to school?	No	
	9.	Have you ever broken a rule?	No	
	10.	Do you sometimes feel angry when you don't get your way?	No	
	11.	Do you sometimes feel like making fun of other people?	No	
	12.	Do you always do the right things?	Yes	
	13.	Are there sometimes when you don't like to do what your parents tell you?	No	
	14.	Do you sometimes get mad when people don't do what you want them to do?	No	