

Why do some school inputs improve skills and others do not?

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Abstract

Whether school inputs improve skills - and if so to what extent - is a matter of great debate, in particular in the context of developing countries. This paper develops a simple framework to understand why particular interventions and school inputs might be more effective at increasing skill acquisition than others. The framework allows for school inputs – in our empirical application modern information technology in the form of a mobile phone – to be a complement or a substitute for either educational inputs or for effort in producing output, each with different theoretical predictions for how technology will affect effort and skills. As a case study, we analyze the randomized provision of mobile phones in the context of an adult literacy programme in Niger, and find that mobile phones increase literacy outcomes because they increase the value of skills learned in the classes rather than being a pure teaching tool.

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1 Introduction

From "No child left behind", via the comparative European Pisa survey to a host of interventions in developing countries, the question of how to improve the accumulation of human capital is a key concern all over the world. And yet, there is no consensus on how to do it, nor whether more resources can provide a cure. This hasn't prevented nearly every education minister from introducing new policies in an effort to improve the quality of teaching. In many cases, these programs are designed to substitute for poor teaching: an extreme example is perhaps a radio maths teaching program in Nicaragua during which children listen to a radio program instead of their teacher during a maths course, leading to more skills acquisition¹. What has received considerable less attention in the debate on education inputs is that in many cases, especially in the developing world, skills taught in school are not very useful later on, and if this is generally understood it might lead to low motivation or low support from parents, and thus low skills acquisition².

This paper analyzes how modern communications and information technology might improve skills, though the model we develop more generally applies to changes to schooling inputs and curriculum (for an overview of the literature on school input and outcomes in developing countries until about 2004, see Glewwe and Kremer, 2006). We focus on modern technology as they have been increasingly used in developed countries and developing countries alike. Of particular interest is through which channels the introduction of technology can lead to increases in skills acquisition. In our model of skills acquisition and endogenous effort, two key variables affect effort and skills: First how useful skills are in producing an output that generates utility. Second, how effective schools are in producing skills from student efforts.

The predictions with respect to the introduction of technology depend on whether technology is a complement or a substitute to teacher quality, or for skills in the output production function. If technology is a substitute for teacher or teaching inputs, then students effort will increase in classes with low-quality teachers, reflecting the substitutability between teaching and technology inputs. If better teachers can make better use of technology, then the predictions can be reversed when the complementarity is strong enough to outweigh the substitutability.

Knowing how to use technology (such as computers and mobile phones) can be of value in itself, in that the technology can be a complement or a substitute for skills in producing output. For example, learning how to use computers increases the usefulness of literacy skills in getting a job. Similarly, knowing how to send an SMS (or text message) increases the usefulness of literacy skills,

¹See the overview in the handbook of education overview article by Glewwe and Kremer (2006). The radio mathematics program was studied by Jamison et al. (1981)

²The above mentioned handbook article on education in developing countries focusses mostly on improving the quality of education through school inputs, and Glewwe and Kremer mention this point only in passing: "there is reason to think that the Kenyan curriculum is not appropriate for the typical student in rural areas".

in particular when sending SMS is cheaper than calling, making technology complementary to skills as is the case in many developing countries. On the other hand technology can substitute for skills, such as the calculator on a phone might substitute for numeracy skills.

We study an intervention designed to increase literacy and numeracy skills. The intervention provides cellphones in the context of an adult literacy program. Partly due to their rapid spread throughout the developing world, mobile phones have drawn substantial attention for their potential impacts on economic development (Bhavnani, et al. 2008; Castells and et al. 2007; Corbett 2008; Donner 2008). As discussed above, there are a number of reasons why cellphones might increase literacy test scores for adult literacy participants.

The first two mechanisms affect how cellphones affect the skill production function in schools. For completely these illiterate learners, cellphones could be a pure teaching tool if they learn the letters and numbers better when they also see them and use them on a cell phone, instead of just following the teacher on the blackboard. In this case the same amount of effort would lead to more skills production and mobile phones might thus act substitutes for poor teaching. We call this hypothesis H1.

However, it is also possible that mobile phones are complements to good teaching in that good teachers might be able to use mobile phones better as a teaching tool (H2). It is also possible that both of these are true: Cellphones could be substitutes for teaching in general, yet the top teachers might be creative enough to further adapt the standard cellphone curriculum, thereby further increasing learning.

The second dimension through which mobile phones can potentially affect learning is by affecting the usefulness of skills in producing some output students care about. Students might understand that the literacy and numeracy skills they learn in class are more useful because they now have access to a cell phone: knowing the numbers from 1 to 10 is more valuable when students are able to call phone numbers, literacy skills are more valuable when you can also send SMS providing an additional motivation for acquiring skills. Mobile phones might thus act as complements to skills in generating some output that students care about (H3). On the other hand, being able to inquire for prices via a phone might make mathematical skills (which might help in forecasting prices) less valuable (H4).

In our intervention, these four channels through which cellphones might affect learning - being a substitute or a complement for either teaching quality and skill usefulness - can all play a role: the usage of mobile phones was not restricted to the class-room and students retained mobile phones after the end of classes. We develop a model of skills acquisition and derive predictions that allow us to test which of these four hypotheses can explain all of the empirical patterns observed. We focus on predictions with respect to effort exerted in class and skills acquired.

We find some evidence that mobile phones increased effort, which suggests that technology are not a direct substitute for skills in producing output (rejecting H4). Moreover, students exerted more effort in classes with teachers of

higher quality, suggesting that mobile phones are a complement to teaching quality (rejecting H1). The empirical results of how the intervention affects effort are thus consistent with two hypotheses : mobile phones are a direct complement for teacher quality (H2), and that students understand that mobile phones technology could also affect the returns to education (H3), leading mobile phones to be indirect complements to teaching quality.

Our model highlights that when technology is a direct complement for teaching quality, i.e. it increases the returns to effort more in high teaching quality classes, it not only motivates students to provide more effort in classes with higher teaching quality, but this also leads to relatively more skills acquisition in classes with higher teaching quality. In the second case, when technology increases the usefulness of skills, this is not always the case. In this case, skills can increase by less in high teaching quality classes than in low teaching quality classes, due to decreasing returns to effort. Empirically, we find that the introduction of mobile phones increased skills, but that this increase was relatively less in high teaching quality classes relative to low teaching classes. This is only consistent with the model in which technology and skills are complements.

The results suggest that adult education classes were successful in increasing skills not because they were useful in themselves as a teaching tool, but because learners understood that the skills they were learning in class were now more useful, given that they had access to phones.

Prior evidence on the pathways through which technology impacts on outcomes and skill acquisition is limited. Our findings that information technology leads to an improvement in skills acquisition are in line with the handful studies of the impact of computer-assisted learning in other contexts. Banerjee, Cole, Duflo and Linden (2007) found that computers increased students' math scores, and was equally effective for all students, whereas a program providing substitute teachers primarily affected the lower part of the distribution. Barrow, Markman and Rouse (2009) show that students in US high schools learned better under a CAL program and hypothesize that the more individualized instruction led to these increases, as they were larger for students in larger classes and with more absenteeism.³

Our model suggests an alternative mechanism through which computers might affect learning: students working on computers might be more motivated, if they understand that the skills they are learning are now more valuable given that they now also know how to use a computer.

The remainder of the paper is organized as follows. In the next section, we provide the background on the setting of the research, as well the randomized intervention. Section 3 describes the model. Section 4 presents some key features of the data. Section 5 outlines our estimation strategy. Section 6 discusses the results, whereas Section 7 concludes.

³Compare with mechanisms

2 Background/intervention⁴

In previous research, Aker et al. (2011) estimated the impact of a mobile phone adult education program in Niger (Project Alphabétisation de Base par Cellulaire, or ABC). Project ABC was implemented by Catholic Relief Services, an international non-governmental organization, in two rural regions of Niger, Dosso and Zinder. Niger is one of the poorest countries in the world and the lowest-ranked country on the UN's Human Development Index (HDI). The country's education indicators are particularly striking: 71.3 percent of the population over the age of 15 was classified as illiterate in 2007 (INS and Macro International 2007). The problem of illiteracy is even more pronounced in our study regions: Close to 90 percent of adults in the regions are illiterate, unable to recognize letters or numbers.

While both regions are located in similar agro-climatic zones, they are over 500 km apart and exhibit distinct ethnic and environmental differences. Dosso is approximately 240 km from the capital city (Niamey), is primarily populated by the Zarma and Hausa ethnic groups and depends upon rainfed agriculture and small ruminants. Zinder, in the far east of the country, is located 750 km from the capital, is primarily populated by the Hausa and Kanuri ethnic groups and depends upon rainfed agriculture and both small and large ruminants. Due to these differences, random assignment to treatment status was conducted separately by region.

Of the 140 CRS intervention villages across the two regions, only 117 were eligible for our study. The randomization first stratified villages by region and then by administrative divisions within each region. Randomization into program and comparison groups was then carried out separately within each stratum using a random number generator. Approximately half of the villages (55) were selected to participate in the first year of classes in 2009, with half of these were selected to participate in the ABC program. The same approach was followed for the 2010 cohort (Figure 2). We therefore present tests for the equality of means for the entire sample and by region.

The first phase of the adult literacy program began in February 2009. Conforming to the norms of the Ministry of Non-Formal Education, each village had two literacy classes (separated by gender), with a maximum of twenty-five slots per class. An individual was considered to be eligible for the literacy program if he/she was: 1) a member of a formal or informal producers' association within the village; 2) unable to read or write letters or numbers in any language; and 3) willing to participate in the program. If there were more than fifty eligible students applicants in a village, students were randomly chosen from among all eligible applicants in a public lottery.

The adult education intervention covered eight months of literacy and numeracy instruction over a two-year period. Courses start in February of each year and continue until June, with a seven-month break between June and February due to the agricultural planting and harvesting season. Thus, the 2009

⁴This section follows Aker et al. (2011)

cohort started classes in February 2009 and finished in June 2010. All classes taught basic literacy and numeracy skills in the native language of the village (either Zarma or Hausa), as well as functional literacy topics.

In partnership with CRS, the authors developed a mobile phone module to incorporate into the traditional literacy and numeracy curriculum. Participants in ABC villages therefore followed the same curriculum as those in non-ABC villages, but with two modifications: 1) participants learned how to use a simple mobile phone, including turning on and off the phone, recognizing numbers and letters on the handset, making and receiving calls and writing and reading SMS; and 2) the project provided mobile phones to groups of literacy participants (one mobile phone per group of five people). The mobile phone module began three months after the start of the literacy courses each year, and neither students, teachers nor CRS staff were informed which villages were selected for the ABC project until two weeks prior to the start of the module. Students in ABC villages had less than 6 weeks of practice using mobile phones during class time each year. Literacy courses are held for five days per week for three hours per day. As one day per week was allocated to revision of previous material, teachers in ABC villages were instructed to teach the mobile phone module during this class.

Using the randomized nature of the project allowed Aker et al. to identify the causal relationship between mobile phones and educational outcomes. They find evidence of positive impacts of mobile phones on educational achievements in the short- and longer-term. Adults' writing and math test scores were 10-20 percent higher in ABC villages, suggesting that students achieved an additional year of primary school education in ABC villages. Aker et al. also document that students were more motivated about education.

3 Model

We specify a general Cobb-Douglas output production function, where the proceeds are a function of skills s and the effort spent on producing the good e_y :

$$y = s^\alpha e_y^{1-\alpha}$$

Think of selling goods in an agricultural market where s is the level of skills or of any other search technology, that we can influence, such as the network of price informants and e_y are the hours directly spent on searching for prices.

In this economy, skills can be acquired, but this also requires effort, and we assume more effort is needed for subsequent increases in skills. Let the skill production function be a concave function of effort: $s = e_s^\beta$. Total effort is $E = e_s + e_y$. A farmer's maximization problem is to maximize y over e_s : $\max e_s^{\alpha\beta} (E - e_s)^{1-\alpha}$

The first order condition is:

$$\frac{\partial y}{\partial e_s} = \alpha\beta e_s^{\alpha\beta-1} (E - e_s)^{1-\alpha} + (1 - \alpha) e_s^{\alpha\beta} (E - e_s)^{-\alpha} (-1) = 0$$

The optimal level of effort to invest into skills is

$$e_s = E \frac{\alpha\beta}{1 - \alpha + \alpha\beta}$$

The derivatives of effort with respect to teaching inputs (β) and skill effectiveness (α) are as follows

$$\begin{aligned} \frac{\partial e_s}{\partial \alpha} &= E \frac{\beta[1 - \alpha + \alpha\beta] - \alpha\beta(-1 + \beta)}{[1 - \alpha + \alpha\beta]^2} \\ &= E \frac{\beta}{[1 - \alpha + \alpha\beta]^2} > 0 \end{aligned}$$

$$\frac{\partial e_s}{\partial \beta} = E \frac{\alpha(1 - \alpha)}{[1 - \alpha + \alpha\beta]^2} > 0$$

Very simply stated, the more easily proceeds can be affected by investing into skills, which is a combination of β (how effective the skill production function is) and α (how strongly skills impact on proceeds), the more of total time is spent on producing skills. This is formally shown in the positive first derivative of e_s with respect to α, β .⁵

We now show four simple ways of incorporating mobile phone technology in this stylized model. First, mobile phone technology can improve skill creation. In our introduction, we referred to this channel as H1. We specify this as $s = e_s^{\beta+t'}$ where t' is the exogenous technology, and a positive number in the unit interval. All else equal, the same level of effort is now more effective in creating skills. The optimal level of effort in the skills production model is:

$$e_s = E \frac{\alpha(\beta + t')}{1 - \alpha + \alpha(\beta + t')}$$

The first derivative of e_s with respect to t' is positive, indicating that when effort becomes more effective for skill creation, more effort is put into acquiring them:

$$\frac{\partial e_s}{\partial t'} = E \frac{\alpha(1 - \alpha)}{[1 - \alpha + \alpha(\beta + t')]^2} > 0$$

This model predicts that teaching quality and technology are substitutes, as the increase in effort is lower when teaching quality is initially higher:

⁵Note that the partial derivative of outcomes with respect to α or β in this model are smaller than the total derivative, as effort is also increased by increasing α or β . The partial derivatives are when we take the derivative of s , keeping e_s fixed. Glewwe and Kremer (2006) highlight this as one of the reasons prospective and retrospective evaluations differ. In this paper we only consider the total derivatives.

$$\frac{\partial^2 e_s}{\partial \beta \partial t'} = -E \frac{2\alpha(1-\alpha)\alpha}{[(1-\alpha) + \alpha(\beta + t')]^3} < 0 \quad (1)$$

In general, overall skills production is increased with technology⁶ and the second derivative of skills with respect to teaching quality and technology is positive⁷.

$$\frac{\partial^2 s}{\partial \beta \partial t'} > 0$$

Introducing complementarities between teaching quality and technology (H2) in this model is simple by specifying $s = e_s^{\beta+t'+\delta\beta t'}$, where $\beta t'$ captures the complementarity and δ is a measure of the degree of complementarity. Note that this formulation includes the possibility that technology is also a substitute (by including t'). In this case, effort can increase or decrease, depending on the degree of complementarity between skills and teaching quality (as well as the other parameters)

$$\frac{\partial^2 e_s}{\partial \beta \partial t'} \begin{cases} > 0 \text{ if } \delta > \delta\alpha + 2\alpha + \alpha\delta\beta + (1 + \delta\beta)\alpha(1 + \delta t') \\ < 0 \text{ otherwise} \end{cases} \quad (2)$$

This allows us a test between the complementarity and substitutability of technology and teaching quality: When $\frac{\partial^2 e_s}{\partial \beta \partial t'} > 0$ then teaching quality and skills cannot be pure substitutes.

Another prediction of the teacher complementarity model is that

$$\text{if } \frac{\partial^2 e_s}{\partial \beta \partial t'} > 0, \text{ then } \frac{\partial^2 s}{\partial \beta \partial t'} > 0$$

Intuitively, if the introduction of technology leads to a larger increase in effort in higher quality teachers, then skills will also rise more in higher quality classes.

A third way in which a technology such as mobile phones can have effects, is by directly increasing the effectiveness of skills in producing outcomes (H3). In our concrete setting, when you have access to mobile phones and you are literate, you can make use of SMS to inquire for prices. We model the increasing effectiveness of skills through technology as follows: $y = s^{\alpha+t''} e_y^{1-\alpha}$. The optimal level of effort in the skill effectiveness model is

$$e_s = E \frac{(\alpha + t'')\beta}{1 - \alpha + (\alpha + t'')\beta}$$

⁶As an artifact of our Cobb-Douglas technology, when β very small, skills decreases when teaching quality increases. Intuitively, the derivative of skills with respect to effort approaches ∞ as $\beta \rightarrow 0$. We exclude this case from our subsequent discussion. In terms of the model, it is easy to incorporate this by bounding β, α away from zero; or by assuming that even without effort in class, students have some initial low level of skill \underline{s} . Only the first of our tests depends on this assumption.

⁷The formulas not presented in the text are too long and often quite unintuitive. They will form part of an appendix in subsequent drafts.

$$\frac{\partial e_s}{\partial t''} = E \frac{\beta(1-\alpha)}{[1-\alpha+(\alpha+t'')\beta]^2} > 0$$

As in the model where skills are direct complements to teaching quality, technology and teaching quality can act as complements or substitutes for teaching quality in increasing effort.

$$\frac{\partial^2 e_s}{\partial \beta \partial t''} = E \frac{(1-\alpha)((1-\alpha)-(\alpha+t'')\beta)}{[(1-\alpha)+(\alpha+t'')\beta]^3} \leq 0$$

The model is similarly ambivalent on whether technology is a substitute or a complement for teaching quality in producing skills:

$$\frac{\partial^2 s}{\partial \beta \partial t''} \leq 0$$

In particular, we note that

$$\text{when } \frac{\partial^2 e_s}{\partial \beta \partial t''} > 0, \quad \frac{\partial^2 s}{\partial \beta \partial t''} \leq 0$$

This means that when the introduction of technology increases more in classes with higher quality teaching, then this does not necessarily also lead to a larger increase in skills in higher quality teaching. Intuitively, the question is whether a larger effort leads to more skills in the face of decreasing returns to effort. It is thus possible for skills to increase less in better teacher classes, while effort in these classes rises by more.

A fourth way in which technology can affect output production is by being a substitute for skills (H4). The simplest formulation of this would be one where $y = (s)^\alpha e_y^{1+t'''} - \alpha$. In the output production function, the effort spent on producing output (which is total time minus effort spent on producing skills) becomes more effective. In effect this means that technology and skills are substitutes. When technology increases, effort is decreased

$$\frac{\partial e_s}{\partial t'''} = -E \frac{\alpha\beta}{[1+t''' - \alpha + \alpha\beta]^2} < 0$$

Since in the other three models, technology increases the effort exerted by students this is the basis for one of our tests.

The following summarizes the different predictions of the model with respect to complementarity and substitutability for effort and skills that we discuss in the empirical section.

We summarize the models, using T to denote technology in general:

- H1. T substitutes for teaching quality (teaching substitute)
- H2. T complements teaching quality (teaching complement)
- H3. T complements skills in producing output (skill complement)

H4. T substitutes for skills in producing output (skill substitute)

We summarize the theoretical predictions that we will use to test the four potential pathways for mobile phone impacts.

- P1. Model 4 predicts $\frac{\partial e_s}{\partial T} < 0$, whereas models 1,2,3 predict $\frac{\partial e_s}{\partial T} > 0$ ⁸
- P2. Model 1 predicts $\frac{\partial^2 e_s}{\partial \beta \partial T} < 0$, whereas models 2,3 are compatible with either $\frac{\partial^2 e_s}{\partial \beta \partial T} < 0$ or $\frac{\partial^2 e_s}{\partial \beta \partial T} > 0$. This implies that if $\frac{\partial^2 e_s}{\partial \beta \partial T} > 0$, then model 1 is rejected.
- P3. Model 2 predicts $\frac{\partial^2 s}{\partial \beta \partial T} > 0$ when $\frac{\partial^2 e_s}{\partial \beta \partial T} > 0$, whereas model 3 is compatible with either $\frac{\partial^2 s}{\partial \beta \partial T} < 0$ or $\frac{\partial^2 s}{\partial \beta \partial T} > 0$. i.e. if $\frac{\partial^2 s}{\partial \beta \partial T} > 0$ then model 2 is rejected.

P1. Intuitively, in order to test models 1,2,3 versus model 4, we note that effort increases in the first three, whereas it decreases in the fourth model. Intuitively, in the first three model skills and technology are complements in producing output but in the fourth model they are substitutes.

P2. To test between models 1 (teacher substitute) on the one hand and 2 (teacher complement) and 3 (skill complement) on the other, we note that in the latter models, the interaction term of teacher quality with technology can have a positive sign. Intuitively, in the first model, teacher quality and technology are substitutes. In the second model, technology is a complement to teaching quality, or can act as such, when technology and skills are complements. When the complementarity is strong enough, technology can lead to a larger increase in high teaching quality classes. In model 1, technology always leads to a larger increase in low teaching quality classes.

P3. Under H2, when technology leads to relatively larger increase in effort in higher teaching quality classes, then skills also rise by more. Under H3 skills can rise by more or less.

4 Data⁹

The study timeline is presented in Figure 1. In the course of the project, three types of data were collected, a household survey, student test scores and administrative data on student attendance and teacher characteristics. The analysis in this paper relies on the administrative data recording student attendance, as well as the information on the teacher quality.

⁸This implies that $\frac{\partial s}{\partial T} < 0$, whereas models 1,2,3 (usually) predict $\frac{\partial s}{\partial T} > 0$

⁹This description follows Aker et al.

4.1 Student and Teacher Data

Data on student-level attendance, teacher attendance and teacher-level characteristics were collected for each class.¹⁰ The top part of Table 1 shows that there is no difference between ABC and non-ABC villages in terms of teacher characteristics. Our primary indicator for teacher quality is the level of education of the teacher.

The student-level attendance is our measure of student effort. Panel B of Table 1 shows our measures of student effort. We do not know much about the students who are not in our survey, so that we only include a dummy for whether they are female or male. Panels C and D of Table 1 show the skills acquired and the baseline skills respectively.

4.2 Pre-Program Characteristics of ABC and Non-ABC Students

We briefly document that the randomization worked. Panel A of Table 1 show that teachers are similar across ABC and non-ABC, and that baseline z-scores are similar. The bottom panel of table provides evidence of the comparability of the program and comparison groups for the pre-intervention outcomes (Table , Panel B). When comparing normalized test-scores, we cannot reject the equality of means for pre-program writing test scores in the full sample, although math test scores at the baseline are higher in non-ABC villages¹¹. While the magnitude of the difference in math is tiny (equivalent to 1 person in 2 non-ABC classes being one level higher), the difference is statistically significant. However, overall, baseline writing and math scores for both program and comparison villages were close to zero, suggesting that the project selected participants who were illiterate and innumerate prior to the start of the program. To account for the small but significant differences at baseline, we implement a first difference strategy.

The top part of table 2 also suggests that the randomization was successful in creating groups comparable along observable dimensions, based on the household characteristics for a sub-sample of our observations. Along a number of dimensions differences in pre-treatment household characteristics are small and insignificant (Table , Panel A). Average household size was a bit over 8. Children’s educational achievements were similarly low: less than 10 percent of children aged 7-15 had ever attended primary school. Thirty percent of households in the sample owned a mobile phone prior to the start of the program, with eighty percent having access to a mobile phone within the village. Over

¹⁰At the student level, a detailed household survey was collected, interviewing a total of 1,038 literacy students across 100 villages. A baseline household survey was conducted in January 2009, with follow-up surveys in January 2010. Each survey collected detailed information on household demographics, assets, production and sales activities, access to price information, migration and mobile phone ownership and usage.

¹¹This is true also when we use the raw scores. In this paper we use normalized test scores throughout, since the tests across rounds were administered slightly differently

50 percent of respondents had used a mobile phone in the few months prior to the baseline, although almost exclusively for receiving calls.

5 Econometric specification and identification strategy

We present the econometric specification for conducting our three tests. In the first test, (P1), We focus on whether teacher quality and technology are complements or substitutes when determining the amount of effort students put in. We use simple reduced form regression specifications, using as our identification strategy our randomized intervention. Whether effort is increased due to the intervention is the basis of our first test.

$$attend_{icv} = \alpha + \beta_1 ABC_v + \beta_2 TQ_{cv} + female_{iv} + cohort_v + \theta_r + \mu_{cv} + \varepsilon_{icv}$$

$attend_{icv}$ is our outcome of interest, specifically the percentage of adult literacy classes that student i attended in classe c . ABC_v is the treatment status indicator of village v , $cohort_v$ is a dummy for whether the class was part of the 2010 cohort (as opposed to the 2009 cohort), and θ_r are geographic fixed effects at the regional or sub-regional level (where the latter is the level at which we randomized). $female_{iv}$ is a dummy for whether the student is female. TQ_{cv} is the quality of the teacher in class and village cv . The error term consists of μ_{cv} , a common class-level error component capturing common shocks, and ε_{icv} , which captures unobserved student ability or idiosyncratic shocks. We cluster the error term at the class level.

The coefficient β_1 captures the average impact of the mobile phone education program on the effort level of students, β_2 how teacher quality affects student participation. The test we conduct is the following:

(P1) If $\beta_1 > 0$ reject H4 (H4: technology substitutes for skills)

If $\beta_1 > 0$ we can then test whether mobile phones and teacher quality are complements or substitutes in the student effort equation using the following equation:

$$attend_{icv} = \alpha' + \beta_1' ABC_v + \beta_2' TQ_{cv} + \beta_3' ABC_v TQ_{cv} + female_{iv} + cohort_v + \theta_r + \mu_{cv} + \varepsilon_{icv}$$

where $ABC_v TQ_{cv}$ is the interaction between teacher quality and mobile phones. The coefficient of interest is β_3' . If β_3' is positive then mobile phones act as a complement for teacher quality.

(P2) If $\beta_3' > 0$ reject H1 (H1: technology substitutes for teaching quality)

If $\beta'_3 > 0$, we can then test whether mobile phones are direct complements for teacher quality or are complements to skills by turning to the skills regression. $Skills_{icv}$ is the Z-score of the test score on literacy or numeracy tests, or a combined score. Because of baseline differences in skills, we implement a difference in difference approach.

$$skills_{icv} = \alpha'' + \beta''_1 ABC_v + \beta''_2 TQ_{cv} + \beta''_3 ABC_v TQ_{cv} + female_{iv} + cohort_v + \theta_r + \mu_{cv} + \varepsilon_{icv}$$

where $ABC_v TQ_{cv}$ is the interaction between teacher quality and mobile phones. The coefficient of interest is β''_3 . If β''_3 is positive then mobile phones act as a complement for teacher quality.

(P2) If $\beta''_3 < 0$ reject H2 (H2: technology is a direct complement to teacher quality)

6 Results and Discussion

We first show that effort is indeed correlated with test scores in Table 3. There is a positive association between effort, as measured by the proportion of classes attended and math test scores. An increased effort of one standard deviation is associated with an increase in math test scores by between 0.085 and 0.14 standard deviations. For writing the effect is smaller, and the statistical significance depends on the covariates included. An increased effort of one standard deviation is associated with an increase in math test scores by between 0.045 and 0.125 standard deviations. For the combined math and literacy score, an increased effort of one standard deviation is associated with an increase in test scores by between 0.07 and 0.14 standard deviations. Due to omitted variables bias (for example of ability), this is merely an association and does not necessarily reflect a causal relationship. We now move on to our empirical tests.

Table 4 contains little empirical evidence that effort is substantially increased through the program, in general, we cannot reject that it is zero. In Column 1 of Table 4, a simple difference specification finds that effort is increased by 4% due to the ABC, and this is significant at the 5% level of significance, though previous columns show that this finding is not robust to the inclusion of various controls, a result we will return to in the discussion. Appendix Table 1 shows that the patterns are similar for different functional forms of attendance. Again, there is only very little evidence that effort was increased due to the project.

While we do not find differences in attendance – perhaps due to attendance incentives provided by the program – we provide additional evidence on student motivation that suggests that students in ABC villages are more the enthusiastic about learning. At the end of classes, students in all villages were invited to call a “hotline” to express their support for adult education classes. Students were informed that the village with the highest number of calls would receive education “kits”, comprised of chalk and notebooks. These materials are provided free by the literacy program and by local schools, and therefore have little to no

market value and no alternative use outside of education. Since students had to pay for the calls, we interpret it as a more reliable measure of participants' interest in education than any hypothetical survey measure. Appendix Table 2 (taken from Aker et al.) presents the results of a regression of the ABC indicator variable on two outcome measures, namely, whether at least one person in the village called the hotline and the number of calls received per village. While the interpretation of the ABC coefficient is bundled (e.g., the gift and interest in education), the results provide suggestive evidence of the program's impact on upon students' interest in education. As compared with a mean of 40 percent in non-ABC villages, students in ABC villages were 22 percentage points more likely to call the hotline than their non-ABC counterparts. Students in ABC villages were also more likely to call the hotline more frequently (a .514 call increase).

On the basis of these two pieces of evidence, we conclude that there is some reason to believe that effort and motivation in ABC classes was not lower (which would be the prediction if technology were a substitute for skills), and that it is likely that the complementarity between skills and mobile phones outweighs the substitutability.

Table 5 presents evidence that technology and teacher quality are complements in motivating students, suggesting that they are not substitutes and ruling out (H1). Column 1 shows that, when students are in a class with mobile phones, attendance increases by 2.0 percentage points for every year of education of the teacher, which is significant at the 5% level of significance. Column 2 includes sub-region fixed effects: the coefficient on the interaction is slightly reduced to 1.8 percentage points, significant at the 10 percent level. Columns 3-6 highlight that these results are robust to different functional forms of attendance. As mentioned, this suggests that mobile phones are complements to teacher quality, so we can rule out that they function as pure substitutes for teaching by teachers.

Table 6 turns to our last test, and document that skills are increased less in high teaching quality classes than in low teaching quality classes. Columns 1 and 2 present results for math test scores, columns 3 and 4 for literacy test scores and columns 5 and 6 for a combined test score. Overall, the coefficient on the interaction between the years of education of the teacher and being in a mobile phone class is negative, though the level of significance does depend on the covariates included. When we include sub-region fixed effects, which is the level at which the program was randomized, the coefficients are significant at the 5% level of significance. This suggests that mobile phones are not direct complements for the teaching quality of teachers.

7 Conclusion

Education systems in developing countries lag behind in international comparisons, and adult education programs - an important part of the educational system - often perform particularly badly. The success of various interventions

trying to improve education outcomes has been of mixed success. This paper studied an mobile phone intervention in the context of an adult literacy class. The rapid expansion of mobile phone coverage and adoption in sub-Saharan Africa suggests that a broad spectrum of populations (urban and rural, rich and poor, men and women) are already using this technology for social and commercial reasons. The paper suggests that students view mobile phones as complementary to the skills they are learning in class. Put differently, our results suggests that it has been particularly successful, because it harnessed the motivation of learners, who understand the immediate benefits from knowing letters and numbers when they have a cell phone.

This insight generalizes to many education programs and interventions in developing countries: the skills that are taught are not always particularly useful for the lives of the learners. Using technology, whether mobile phones or computers, promises higher rewards for the skills learned in class and thus can stimulate student effort and learning.

8 Bibliography

[INCOMPLETE]

Figure 1: Timeline

2009 cohort

	baseline Jan 10	June 2009	June 2010
ABC	un-treated	treated	
non-ABC	un-treated	un-treated	

2010 cohort

	baseline Jan 10	June 2009	June 2010
ABC	un-treated		treated
non-ABC	un-treated		un-treated

Table 1: Baseline Household Descriptive Statistics (by Treatment Status)

	ABC Mean	Non-ABC Mean	Diff (s.e.)
Panel A: Teacher data			
Age	32.80	33.03	-0.22 (1.15)
Education (number of years)	8.50	8.42	0.08 (0.26)
Local (1=Yes, 0=No)	0.72	0.77	0.05 (0.06)
Panel B: Attendance			
Percent of classes attended	0.84	0.81	0.03 (0.01)***
Panel C: Skills acquired			
5-month literacy z- score	0.09	-0.09	.18 (.03)***
5-month numeracy z- score	0.08	-0.08	.16 (.03)***
5-month combined math and lit z-score	0.09	-0.10	.19 (.03)***
Panel D: Baseline skills data			
baseline literacy z- score	-0.01	0.01	-.03 (.03)
baseline numeracy z- score	-0.04	0.04	-.08 (.03)***
baseline combined math and lit z-score	-0.03	0.03	-.06 (.03)**

Notes: Table displays summary statistics for treatment (Column 1) and control group (Column 2). Column 3 reports the difference. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively.

Table 2: Difference in Household level variables between ABC and non-ABC Villages

	ABC	NonABC	Coeff (s.e.)
Age	37.86	37.18	0.69 (.77)
Head of Household (1=Yes, 0=No)	0.56	0.55	0.01 (.03)
Farmer is respondent's main occupation	0.80	0.79	0.01 (.03)
Housewife is respondent's main occupation	0.18	0.19	-0.01 (.02)
Number of household members	8.42	8.33	0.09 (.25)
Percent Children <15 with some primary education	0.10	0.09	0.01 (.01)
Number of asset categories owned	4.97	4.99	-0.01 (.11)
Number of houses owned	3.18	3.12	0.06 (.13)
Own mobile phone (1=Yes, 0=No)	0.30	0.30	0.0 (.03)
Respondent has access to mobile (in HH or village)	0.79	0.76	0.03 (.02)
Used mobile phone since last harvest (1=Yes, 0=No)	0.54	0.57	-0.03 (.03)
Number times used mobile phone since last harvest	6.67	7.26	-0.59 (.47)

Notes: Table displays summary statistics for ABC (Column 1) and non-ABC (Column 2). ***, **, * denote statistically significance at 1, 5, 10 percent, respectively.

Table 3: Association of classes attended (effort) and skills acquired

	Math Z-Score			Writing Z-Score			Combined Z-Score		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Percent Classes Attended	0.345** (0.134)	0.572*** (0.132)	0.455*** (0.141)	0.176 (0.146)	0.496*** (0.144)	0.290* (0.162)	0.283* (0.146)	0.569*** (0.138)	0.397** (0.156)
Teacher Education (Years)		0.0573** (0.0250)	0.0493* (0.0293)		0.0572*** (0.0214)	0.0410** (0.0201)		0.0617*** (0.0227)	0.0482** (0.0242)
Teacher from Same Community		-0.107 (0.120)	-0.228 (0.144)		-0.366*** (0.108)	-0.172 (0.117)		-0.266** (0.116)	-0.216* (0.130)
Teacher Age		-0.00552 (0.00596)	-0.0119* (0.00613)		0.000628 (0.00575)	-0.00947** (0.00475)		-0.00240 (0.00573)	-0.0114** (0.00510)
Student Sex		-0.305*** (0.109)	-0.301*** (0.0888)		-0.463*** (0.0972)	-0.454*** (0.0742)		-0.421*** (0.100)	-0.415*** (0.0800)
Sub-region fixed effects	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
Number of observations	2,410	2,307	2,307	2,408	2,302	2,302	2,398	2,297	2,297
R ²	0.115	0.064	0.163	0.139	0.120	0.210	0.125	0.103	0.192

Notes: The results are for data for the 2009 cohort in June 2009 only, tests were conducted immediately after the literacy training. The sub-region level was the level of randomization between ABC and across cohorts. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the class level.

Table 4: Technology and Effort

Dependent Var: Attendance	(1)	(2)	(3)
ABC or non-ABC village	0.047** (0.023)	0.030 (0.020)	0.0058 (0.017)
Teacher Education (Years)		-0.0036 (0.0053)	-0.0086* (0.0045)
Teacher Age		0.0012 (0.0013)	0.00096 (0.0010)
Teacher from Same Community		0.012 (0.028)	0.029 (0.024)
Cohort of Learners		0.082*** (0.0096)	0.075*** (0.0075)
Student Sex		0.032 (0.020)	0.029* (0.017)
Dosso Region = 1 Zinder =0		-0.0032 (0.026)	
Sub-region fixed effects	No	No	Yes
Number of observations	5,279	5,088	5,088
R ²	0.008	0.110	0.197

Notes: ABC villages are the villages in which traditional literacy training was complemented by mobile-phone based literacy training. The results are for data pooled for the 2009 cohort in the period from January to June 2009 and for the 2010 cohort in the period from January to June 2010. The sub-region level was the level of randomization between ABC and across cohorts. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the class level.

Table 5: Technology and Teacher Quality: Substitutes or Complement

	Proportion Classified Attended		Total Classes Attended		Log Total Classes Attended	
	(1)	(2)	(3)	(4)	(5)	(6)
Interaction of ABC and Teacher Education (Years)	0.020** (0.0097)	0.018* (0.010)	0.058** (0.029)	0.057* (0.030)	1.65*** (0.56)	1.69*** (0.54)
ABC village	0.027 (0.019)	0.0013 (0.017)	0.13** (0.060)	0.053 (0.055)	2.21* (1.17)	0.47 (1.01)
Teacher Education (Years)	-0.011 (0.0077)	-0.016** (0.0075)	-0.020 (0.025)	-0.037 (0.024)	-0.98** (0.38)	-1.32*** (0.41)
Teacher Age	0.0016 (0.0014)	0.0014 (0.0011)	0.0070 (0.0048)	0.0072* (0.0038)	0.11 (0.091)	0.12* (0.074)
Teacher from Same Community	0.024 (0.028)	0.039 (0.024)	0.071 (0.093)	0.099 (0.090)	1.42 (2.07)	2.90 (1.88)
Sex of Teacher	0.044 (0.031)	0.029 (0.028)	0.18 (0.11)	0.15 (0.10)	2.44 (2.04)	1.89 (1.89)
Round of literacy data-collection	0.085*** (0.0093)	0.078*** (0.0081)	0.39*** (0.13)	0.40*** (0.11)	5.76*** (1.62)	5.62*** (1.52)
Student is female	0.0093 (0.028)	0.014 (0.024)	-0.036 (0.098)	-0.021 (0.086)	1.03 (1.83)	1.35 (1.55)
Dosso Region = 1 Zinder =0	-0.0039 (0.025)		0.018 (0.071)		0.32 (1.58)	
Log Total days taught			1.50*** (0.48)	1.61*** (0.43)		
Total days taught					0.91*** (0.13)	0.91*** (0.11)
Sub-region fixed effects	No	Yes	No	Yes	No	Yes
Number of observations	5,088	5,088	5,088	5,088	5,088	5,088
R ²	0.120	0.202	0.056	0.107	0.286	0.351

Notes: ABC villages are the villages in which traditional literacy training was complemented by mobile-phone based literacy training. The results are for data pooled for the 2009 cohort in the period from January to June 2009 and for the 2010 cohort in the period from January to June 2010. The sub-region level was the level of randomization between ABC and across cohorts. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the class level.

Table 6: Are skills increased more in classes with better teachers

Difference in Difference specification	Math Z-scores		Write Z-scores		Combined Z-score	
	(1)	(2)	(3)	(4)	(5)	(6)
Interaction of ABC and Teacher Education (Years)	-0.065* (0.036)	-0.067** (0.034)	-0.035 (0.033)	-0.068** (0.032)	-0.054 (0.035)	-0.076** (0.032)
ABC or non-ABC village	0.16** (0.072)	0.13* (0.068)	0.18*** (0.069)	0.16** (0.070)	0.19*** (0.070)	0.16** (0.070)
Teacher Education (Years)	0.023 (0.018)	0.028 (0.019)	0.0050 (0.019)	0.016 (0.020)	0.014 (0.018)	0.023 (0.020)
Teacher Age	0.0011 (0.0041)	-0.0032 (0.0042)	0.0034 (0.0049)	-0.0036 (0.0047)	0.0027 (0.0045)	-0.0037 (0.0045)
Teacher from Same Community	-0.23** (0.095)	-0.24** (0.10)	-0.11 (0.10)	-0.16 (0.11)	-0.18* (0.10)	-0.22* (0.11)
Sex of Teacher	-0.12 (0.097)	-0.16* (0.094)	-0.13 (0.094)	-0.16* (0.094)	-0.14 (0.096)	-0.17* (0.094)
Round of literacy data-collection	-0.0020 (0.036)	-0.012 (0.035)	0.015 (0.037)	-0.0036 (0.038)	0.0069 (0.036)	-0.0096 (0.037)
Student Sex	-0.36*** (0.092)	-0.37*** (0.083)	-0.43*** (0.081)	-0.45*** (0.076)	-0.44*** (0.086)	-0.45*** (0.079)
Dosso Region = 1 Zinder =0	0.18** (0.082)		-0.16* (0.093)		-0.0045 (0.087)	
Sub-region fixed effects	No	Yes	No	Yes	No	Yes
Number of observations	4,903	4,903	4,886	4,886	4,881	4,881
R ²	0.065	0.111	0.092	0.136	0.089	0.135

Notes: ABC villages are the villages in which traditional literacy training was complemented by mobile-phone based literacy training. The results are for data pooled for the 2009 cohort in the period from January to June 2009 and for the 2010 cohort in the period from January to June 2010. The sub-region level was the level of randomization between ABC and across cohorts. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the class level.

Table A1: Technology and Effort - Alternative functional forms for attendance

	Total days attended		Logarithm of Total days attended	
	(1)	(2)	(3)	(4)
ABC or non-ABC village	2.42*	0.77	0.14**	0.071
	(1.25)	(1.07)	(0.065)	(0.058)
Total days taught	0.88***	0.87***		
	(0.13)	(0.11)		
Log Total days taught			1.47***	1.54***
			(0.50)	(0.45)
Teacher Education (Years)	-0.33	-0.60**	-0.0017	-0.016
	(0.30)	(0.29)	(0.017)	(0.015)
Teacher Age	0.083	0.089	0.0053	0.0052
	(0.085)	(0.067)	(0.0043)	(0.0034)
Teacher from Same Community	0.58	2.04	0.031	0.059
	(2.02)	(1.86)	(0.090)	(0.089)
Round of literacy data-collection	5.19***	4.70***	0.37***	0.37***
	(1.68)	(1.50)	(0.13)	(0.12)
Student Sex	2.30*	2.28**	0.053	0.052
	(1.37)	(1.15)	(0.068)	(0.058)
Dosso Region = 1 Zinder =0	0.40		0.012	
	(1.60)		(0.069)	
Sub-region fixed effects	No	Yes	No	Yes
Number of observations	5,279	5,088	5,088	5,088
R ²	0.048	0.102	0.277	0.344

Notes: ABC villages are the villages in which traditional literacy training was complemented by mobile-phone based literacy training. The results are for data pooled for the 2009 cohort in the period from January to June 2009 and for the 2010 cohort in the period from January to June 2010. The sub-region level was the level of randomization between ABC and across cohorts. ***, **, * denote statistical significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the class level.

Table A2. Effect of ABC on Student Interest in Education

Dependent variable:	<i>Called hotline</i>	<i>Number of calls</i>
	Coeff(s.e.)	Coeff(s.e.)
ABC	.233*(.119)	.514*(.250)
R ²	0.05	0.03
Mean (s.d.) of non-ABC group	0.400(.496)	1.05(.238)

coefficient is the coefficient on an ABC variable. Robust standard errors are in parentheses. *, **, *** denote statistically significant at 10, 5 and 1 percent levels, respectively.