Impact of Low-Cost, On-Demand, Information Access in a Remote Ghanaian Village

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ABSTRACT
Technology projects are finding ways to provide information to people living in rural poverty. However, using information to affect health or farming practices requires overcoming unique challenges including illiteracy and lack of electricity. We examine the effects of a low-cost audio computer ("Talking Book")−a battery-powered, durable, handheld device that enables users to create and listen to recordings and copy recordings between devices−for improving learning opportunities and knowledge sharing in such environments. In northern Ghana, we studied the impact of giving rural, illiterate people on-demand access to guidance created by local experts. Our evaluation suggests that Talking Books can make a significant impact on learning and behavior change in villages with low literacy rates and no electricity.

General Terms
Design, Economics, Reliability, Experimentation, Human Factors.

Keywords
Knowledge transfer, information dissemination, audio, illiteracy, low-cost technology, agriculture production.

1. INTRODUCTION
In developing countries, nearly 1.5 billion people live without electricity [1] and 752 million are illiterate [2]—two constraints that make accessing information challenging. To exacerbate this problem, the majority of these people live in rural areas [3], [4], which are often hard to reach because of inadequate roads. Information about farming techniques is particularly important because agriculture is a major source of livelihood for most rural people though they often rely on rudimentary methods [5].

One intervention that illustrates the difficulties in reaching these farmers is agricultural extension. Agents travel to villages to increase the productivity of farmers. However, extension services face various obstacles including limited staff who must reach large numbers of geographically dispersed farmers. Agent-to-farmer ratios are extremely high (as high as 1:6000 in Ghana [6]) and the majority of small, marginal farmers worldwide receive only one-third of all extension resources [7]. For the small fraction of rural farmers who are reached, visits are often inadequate for many reasons including under-skilled agents who are not held accountable for the services they provide [7].

To enable local experts to reach remote, rural people with accessible information, Literacy Bridge created a low-cost audio computer called the "Talking Book". The Talking Book is a handheld, durable, battery-powered device that enables users to create and listen to audio recordings and copy recordings between devices. This device was specifically designed to meet the needs of those who are illiterate or live without electricity—enabling them to listen to information repeatedly and on-demand.

What follows are the findings of a pilot program in a rural village in Ghana. Local experts recorded farming techniques, health guidance, and other educational information onto 21 devices. A committee of local leaders then allocated the devices among residents. The pilot was originally intended to study the feasibility of providing rural villages with health and agriculture information using a Talking Book; however, reports from the qualitative interviews prompted us also to measure the effect of the Talking Book on crop production.

This paper is structured as follows: Section II outlines related Information and Communication Technology (ICT) solutions that disseminate information to rural communities; Section III introduces the Talking Book, including device functionality and the associated program implementation; Sections IV, V, VI, and VII describe the pilot study and findings; Section VIII proposes areas that need future research; and Section IX concludes.

2. RELATED WORK
We focus on how the *illiterate* poor in *remote* areas can *learn* new health and farming practices–a much narrower problem than

ICTD2010, December 13–15, 2010, London, U.K.

"serving the rural poor with information". In this section, we compare and contrast ICT projects in this broader category with the Talking Book.

2.1 Mobile Projects

Applications of mobile technology have shown promise for information delivery, particularly with time-sensitive information such as weather, commodity prices, and job postings. SMS has been used to serve literate populations [8], [9], while operator-based and interactive voice response projects have attempted to target illiterate people [10], [11], [12]. However, the form factor and cost structure of mobile solutions present significant challenges to learning scenarios for two primary reasons. First, to affect behavior change, users often must access learning materials multiple times [13], [14], which would require either an unaffordable smart phone or repeat network calls on a basic phone, each call spanning the duration of the lesson. Mobile network rates across Sub-Saharan Africa, in particular, put this option out of reach for many (with the lowest rates exceeding US$0.20/minute in Kenya, Nigeria, South Africa and Uganda [15]). Second, handset energy costs and recharging logistics may be manageable for accessing small pieces of information, but are less feasible when using a handset to replay audio lessons.

2.2 Radio

The accessibility and affordability of radio gives it great potential for distributing development information in poor areas [16]. However, the transmission costs and barriers to open access present limitations to learning, particularly in regions with low-densities or multiple languages. Learning content must compete for airtime against music and religious programming.

Community Radio (CR) offers an alternative by focusing on societal issues. In countries with progressive CR regulations, repeated, one-way distribution of learning content is proving feasible in urban and dense rural regions [17], [18]. Many CR stations accept mobile calls from listeners to add a participatory element [18], [19].

One prior study describes a "rural" CR station with 800,000 listeners in South Asia [18]. However, this many concentrated listeners would not be possible in the sparsely populated Upper West Region of Ghana (18,478 square km with a population of 576,583 [20]) or in many similar rural regions worldwide. Given the government of Ghana's 25 km limit for CR transmission, a typical station would reach just over 61,000 listeners in the Upper West region (more near the regional capital, less elsewhere)—making it much less cost effective. Another shortcoming of content distribution by radio is the difficulty in collecting metrics on listening statistics and user ratings.

2.3 Infomediaries

Building on the extension worker approach, some programs place technology in the hands of a mediator or community knowledge worker ("infomediary") who is educated enough to use the technology but does not need to be an expert in the domain [13], [21]. By spreading the technology costs over a large number of beneficiaries, they mitigate the cost problems described above for mobile programs. More research is needed to better understand these costs relative to the number of people changing their behavior, i.e. adopting a new practice.

2.4 Other "Featherweight" Devices

Other low-cost audio devices have been deployed and evaluated for rural information access [14]. Devices such as the "Speaking Books" from Books of Hope are affordable ($9-$10), but they are limited to 5-15 minutes of audio that cannot be updated, and they are not conducive to locally produced content at small scale; the minimum order to produce a new Speaking Book is 5000 units [22].

Global Recording Networks offers a hand-wind digital player called the "Saber" designed for rural use [23]. Its audio can be updated from a computer, but it has no microphone for direct recording, and the price puts it out of reach of individual ownership (the bulk purchase price is $45 each for missionary use and $65 for other uses). Commercial digital recorders fall into a similar price range and are less robust [24].

None of these options provide the flexibility for audio to be recorded and copied from one device to another without additional hardware or infrastructure. None of them include customizable audio instructions or interactive applications.

3. THE TALKING BOOK PROGRAM

3.1 Device

The Talking Book (Figure 1) allows users to play, record, and categorize audio recordings and to copy those recordings directly to any other Talking Book. When powered on, spoken instructions lead users through the audio user interface. The instructions are easy to localize and each device can include multiple system languages. To access recordings, users are guided by audio prompts, to which they respond with key presses. For instance, pressing the right and left arrows navigate through categories (e.g. "health", "agriculture", "stories") and once in a category, the up and down arrows rotate through individual messages. The device also supports programmable interactive applications such as multiple-choice quizzes and messages with embedded hyperlinks.

Figure 1. The Talking Book

The current version of the Talking Book is 12 cm x 12 cm x 6.5 cm deep and weighs 225 grams without batteries. Devices are typically powered by two, zinc-carbon, size-D batteries, which we have found in rural markets throughout Ghana for $0.35-0.40. These batteries supply 12-15 hours of typical use; and ongoing engineering improvements are expected to double energy efficiency. A built-in speaker enables group listening, but power can be conserved using earphones. Recordings are stored on an internal microSD memory card, providing between 35 and 140 hours of capacity. To improve robustness and affordability, the device has no display.

Depending on the scale and design of an intervention, this program requires a per capita investment of between $1 and $5 for the device and between $0.50 and $1.00 in annual energy costs.

3.2 Content

The Talking Book enables development organizations (governmental, nonprofit, and for-profit) to share information with rural communities—typically information that teaches new practices but requires repeated listening due to its complexity. The Talking Book also enables rural people to share information with each other and to provide recorded feedback to development organizations.

We have developed a content management application that enables organizations to organize recordings by language and category (e.g. "livestock diseases" or "malaria prevention") and track aggregate usage statistics and user ratings for each recording.

3.3 Program

Today development organizations integrate Talking Books into their programs to accommodate their needs and local context. Regardless of the implementation, our general theory of change is as follows: 1) Residents listen to the recordings, understand the information, and retain the knowledge. 2) They trust the information and apply it in practice. 3) Application of knowledge results in improved livelihood (e.g. better agriculture practices cause increased yield; malaria prevention techniques lead to fewer mosquitoes and outbreaks).

To the extent that this theory becomes a reality in each program, the Talking Book will enable development organizations to spread their messages more efficiently (reaching more beneficiaries with the same budget) and more effectively (increasing their impact as beneficiaries are more likely to retain and apply knowledge). In addition, recorded feedback from users and usage metrics (e.g. play/copy counts for each message) can enable organizations to continually improve a program's implementation.

Literacy Bridge and its partners implement programs in 1) rural villages, where devices are shared communally, 2) health clinics, where patients listen to health guidance while waiting in line, and 3) rural schools, where teachers use the devices to complement literacy lessons. In the future, Talking Books may also become available for purchase in local markets alongside radios and flashlights, once the manufacturing costs drop sufficiently.

The remainder of this paper contains the details and findings from a rural village program.

4. PILOT STUDY OVERVIEW

This study took place in a small village, named Ving Ving, in the Upper West Region of Ghana. Ving Ving is part of a district with roughly 100,000 people, 95% of which live in rural areas [25]. Almost all roads in the district are unpaved and some roads close during the rainy season. This village was selected because it is representative of our target population. Approximate demographics include:

- Population: 970 people, 98 households
- Electricity: No access
- Adult educational level: 77% had never attended school
- Child Education: ~450 children of primary school age with ~200 actually attending school
- Occupation: 100% subsistence farmers
- Main crops: maize, beans, groundnuts, millet, guinea corn, and rice
- Extension visits: once per year
- Access to technology: 10% own radios, 1.5% own mobile phones. Weak reception of a single GSM network was available in portions of the village; no data service.

After selecting the village, we approached local leaders and obtained buy-in for the program. We collected information about their needs and collaborated with local experts in agriculture, health, and education to produce content.

4.1 Program

In January 2009, we began a series of community meetings to launch the pilot. None of the participants or content producers was ever compensated for their involvement. The first meeting was led by local leaders, two Literacy Bridge staffers, and the director of the local Ministry of Food and Agriculture (MOFA) office.

The following components summarize the pilot program:

4.1.1 Committee

The chief and elders agreed to host the program and create a committee of leaders—primarily of young men who spoke English, were more educated than their peers (9-12 years versus 1 year), and had interacted with Literacy Bridge during previous research visits. At our request, women and children were added to the committee before the first meeting. The role of the committee was to support the residents, including training new users and managing the devices. Literacy Bridge staff trained the committee to use the devices in two sessions, each lasting two hours.

4.1.2 Allocation method

Distribution of devices was left up to the leadership committee. Literacy Bridge's only requirement was that the devices were to be exchanged frequently and fairly (e.g. regardless of gender and social class). The committee discussed options and decided on the following: if a resident wanted to use the device, he or she would approach a committee member to borrow a device for a specified timeframe, with a maximum of six days.

4.1.3 Devices

Literacy Bridge funded the 21 devices, which it produced in a lot of 100 units at a unit cost of $105 (not including non-recurring engineering costs that were shared with later production runs). The devices were localized into Dagaare, the local language of Ving Ving. Each device was pre-loaded with recordings as outlined in the subsection below.

4.1.4 Continual support

User training was conducted by the village's pilot committee members. A Literacy Bridge staff member visited the village every two to five weeks to offer technical support and collect feedback. He also provided batteries to encourage usage—enabling us to collect the most feedback.

4.2 Content

Local experts from MOFA, Ghana Education Service, and Ghana Health Service recorded information on the Talking Books. The 27 messages ranged from 30 seconds to 7 minutes, totaling 58 minutes. The categories included:

4.2.1 Agriculture

This category covered topics such as:

- *Fertilizer*. The importance of using animal manure as fertilizer; to keep animals in a confined space to collect their droppings; where to obtain subsidized industrial fertilizer and when to apply it.
- *Soil Preparation*. For better moisture retention and more efficient use of soil, to create beds or plow lanes instead of making mounds; to use a tie-ridge pattern to reduce soil erosion.
- *Planting*. Which month to plant each crop; crop-specific seed grouping and spacing; weeding after planting.
- *Livestock*. How to prevent, detect, and care for sick animals; to clean animal pens everyday to prevent disease.

4.2.2 Health

This category covered nutrition, antenatal care, and health for children under five. Specific topics included monthly antenatal guidance, an overview of a balanced diet, and sanitation best practices.

4.2.3 Education

This category included poems, textbook excerpts, and educational storybooks. Topics ranged from community development to solar energy. Recordings of numbers and the alphabet were included to allow students to practice along.

4.2.4 Stories

This category included local stories focusing on tradition, culture, and morals. Some recordings were humorous.

4.3 Evaluation

To evaluate this program, Literacy Bridge staff interviewed 118 people through a variety of methods. We collected qualitative feedback about the physical device and program implementation (Section V) to answer the following questions:

- How do users react to the devices? Which groups of people are interested in the devices and why?
- Can illiterate users learn to the use the device in a reasonable time with help from peers?
- Does the checkout method promote equitable allocation among users? Are there issues to consider in future programs?
- Did the information on the Talking Books create behavior change? If users applied the health or agriculture guidance, had they seen improved results?

The positive reports of learning and behavior change described in Section V prompted us to look for further support that farmers were applying agriculture guidance. Section VI summarizes our analysis of quantitative harvest data before and after the introduction of Talking Books.

5. EVALUATION OF DEVICE AND PROGRAM

5.1 Methodology

In August 2009 and January 2010 Literacy Bridge staff conducted 37 semi-structured interviews with 23 men and 14 women. Question topics ranged from training, usability, and device allocation to learning, adoption rates, and results. The 30-90 minute interviews were conducted in households and in common village areas. In addition, we conducted eight informal video interviews with five men and three women where users spoke more freely about their experiences. Staff interviewed the farmers in the local dialect and recorded the answers in English.

5.2 Results

5.2.1 Initial Exposure

In general, residents were very interested and excited to use the devices. They said it was visually appealing, that they liked the variety of colors, and were impressed that the device could speak. Witnessing peers use the devices and word of mouth seemed to play a large role in the initial acceptance. Residents reported discussing the device and the information amongst each other and with residents in other villages.

The most common requests for additional or different features included lights for use at night, more pronounced buttons for the blind, an embedded radio, solar or rechargeable power, and a smaller pocket-size version.

5.2.2 Training

Residents were taught by either the leadership committee or a peer. Ease of use generally increased with amount of education; those who were literate or in school seemed to learn quickly, while illiterate residents required more training to understand how to navigate the audio instructions. Children learned at an impressive rate, typically requiring the least training of all groups.

Illiterate users usually required less than 45 minutes of training to be comfortable with listening and recording messages. However, the leaders reported it was common for residents to forget portions of the training the following day.

5.2.3 Allocation

Despite our equity goals, devices were not used or allocated equally across genders and ages. We estimate that the devices reached 34% of households in the village; however, we do not have an accurate count of household members using the devices. Men and school boys used the device most often. Women and the elderly used the devices least. The primary reasons that inhibited use included:

Limited awareness about the program was a problem. Many people did not know about the devices, thought they were only meant for literate people or the committee, or were unaware of how to obtain a device. However, there was strong interest from those who did not use the device: 33 of 35 non-users interviewed said they wanted to use the device. A common suggestion was that the program should be marketed better so that everyone understood how it worked.

- Many residents said there were not enough devices to go around and requested more devices so that more people could benefit. There was one device per 47 residents.
- Some were intimidated because they thought the technology was too complex and feared breaking it.
- Some were hesitant to approach the committee because of existing social dynamics. This seemed to apply mostly to women and the elderly.
- Some thought they had to purchase batteries.
- When asked about alternative allocation solutions, some residents suggested equally dividing the devices

between genders and/or geographic sections of the village.

5.2.4 Usage

Usage varied greatly, but users typically checked out the devices in one-week increments and reported listening to the device a few times during the week, often in groups. Women commonly reported listening to the devices after dinner with their children. There were some reports of men not sharing the devices with their families.

Device-to-device copying was not yet implemented, but users did record their own messages, which were later heard by other users of the same devices. The most common local recordings were stories that taught morals and concerns about local injustices (e.g. how it is wrong that some girls are forced to elope). Many residents enjoyed recording music or programs from the radio to listen to at a later time.

5.2.5 Learning and Behavior Change

When asked if they had learned anything from the device, a resident's ability to recite specific details about the health and agriculture guidance confirmed that they had indeed learned and retained the information.

91% of residents using Talking Books in their homes (32 of 35) said they had applied a new health or agriculture practice. Some farmers said they did not apply portions of the guidance because they could not afford to; for example, one recommended practice required purchasing fertilizer.

In some cases, agriculture guidance was not completely new to a farmer; but behavior change appeared to result when the farmer learned why particular techniques were more effective than others and how to apply these techniques most efficiently. Even then, 71% of people applying the guidance chose to test it on only a portion of their land; this reduced their risk and allowed them to compare the recommended practice with their traditional practice. Figure 2 and Figure 3 show the side-by-side difference of one farmer who applied the Talking Book guidance to a portion of his land.

In addition to people who checked out Talking Books for use in their home, we surveyed 12 other residents who had either learned about the guidance from a neighbor or had used a Talking Book outside of the home. Only 6 of the 12 had applied what they had learned.

The following two quotes demonstrate the enthusiasm farmers had for the information provided by the local agriculture extension office:

"What I learned from the Talking Book is about farming. The agricultural extension officers told us to start clearing our farm lands in April and begin sowing guinea corn, millet and beans in May, and I did. And that we should begin planting groundnuts in early June, which I did as well. I actually finished by the middle of June and these are the groundnuts (shows his plants), and this is how good a yield I get. Before this device, I usually sowed my groundnuts in July and I never get a good yield like this but this year since I listened to these teachings in this device and planted my crops early, I am very pleased with the prospects of the harvest. It is far better than what I usually get and that is one of the great lessons from this device."

"It has a lot of benefits to me. It taught me that we can plant the crops in beds and lanes, that those methods increase the amount of crops per land area compared to mounds which waste land and take up a lot of space. Beds also help accumulate water, prevent erosion and keep the soil within the farm moist. The beds actually make a big difference in terms of keeping the soil moist. Mounds are too high from the ground and they dry up very fast and our crops suffer during insufficient rainfall. Now we can still smile during short periods of draught because planting in beds keeps the soil moist for a little while. Since I heard that from this device, I tried it this year, and I am a woman but people exclaim whenever they see my crops in the farm and I just keep my mouth shut because I know the harvest is going to be good. With the small amount of rain that we get, the beds still keep the water around and the crops stay healthy for up to a week and I go to look at them with smile on my face."

5.2.6 Content and Trust

Farming was by far the most popular category, followed by health. Residents were asked whether there was guidance that they did not trust. 22 out of 24 users said they trusted every message on the device. Many spoke of how they had never heard of modern practices, and only a few questioned a message's validity. A key component of their trust was that the messages were recorded by a local authority. We also suspect the high level of trust was due to the timing of the survey—many had already applied the guidance and seen the initial results. One farmer said he did not trust the guidance for millet, but that he would adopt it if he saw that it worked for a friend. Another farmer said that he did not trust the vaccination messages because he followed the guidance for his fowls and his goats, but all of them still died, which confused him.

Figure 2. Farmer showing maize planted without animal manure. Picture taken August 2009.

Figure 3. Farmer showing maize planted with the manure he obtained from confining his animals, as instructed on the Talking Book. Picture taken August 2009.

5.2.7 Durability and Maintenance

Throughout the year, the Talking Books became dirty and worn, but no device had a broken or cracked exterior. One device had

Figure 4. A Talking Book that had been disassembled by a user.

apparently been disassembled by a user and left in the mud before being reassembled (Figure 4). Dried dirt covered the circuit board, yet the device still functioned properly.

During the pilot, we discovered an electrical design flaw that caused some users to lose recordings every two to four weeks due to file corruption on the memory card. In some cases, devices were rendered inoperable until our staff reformatted and reloaded the card. The source of the problem was the on/off switch that allows a user to immediately cut power to the microcontroller and flash memory card while read/write operations were in progress. To address this problem, we removed the on/off switch and created a sleep mode, which increases battery costs by approximately 2-3% for typical use.

5.3 Limitations

Some of this research may be biased by the selection of residents, which was at times provided by the village's leadership committee. To mitigate positive bias, staff emphasized to those interviewed that feedback would be used to improve future pilots and would not affect how many devices were brought to the village. In addition, some of the interviews were conducted while American volunteers were present, which may have influenced the actions and answers of those interviewed.

6. EVALUATION OF CROP PRODUCTION

In an attempt to validate the reports that Talking Book users were applying the new practices, we collected quantitative data on crop production following the harvest in November 2009 using a between-groups design.

6.1 Methodology

We asked farmers if they had access to Talking Book messages, which we used to compare those who had access to those who did not. In total, 33 surveyed farmers had access to information from the Talking Book either by using the device inside or outside their home or by learning about the messages from a neighbor. We refer to this group as the "treatment group" or "Talking Book users". Another 40 surveyed farmers did not have access to information from the Talking Book—that is, they neither used a device nor heard about the messages it contained. We refer to this group as the "comparison group" or "non-users". This is a non-equivalent control group because users self-selected into the program by checking out a device.

Local staff administered 30-60 minute interviews using a survey questionnaire. Interviews were conducted in the local dialect and answers were recorded in English. Information was collected on the following measures.

6.1.1 Crop Production

We asked each farmer about the number of bags[1] they harvested in 2008 (the previous year) and in 2009 (the current year) for millet, maize, beans, and groundnuts. We computed total crop production for each farmer for each year by summing crop production for these four crops. Farmers often decide to shift their allocation of land, labor, and other factor inputs between various types of crops each year. Therefore, we use total crop production rather than production for each of the four individual crops as the dependent variable to evaluate the impact of exposure to information on the Talking Book. Crop production for each farmer in 2008 was used as a control variable, since a great deal of variance in crop production is driven by a host of factors that are unique to each farmer.

6.1.2 Change in practices and inputs

For each of the four crops, we asked about changes in practices from 2008 to 2009 for the following factors: human labor, land farmed, animal labor, use of pesticides, and use of fertilizer. For each answer, staff translated the response into the following scale:

-2: large decrease

-1: little decrease

0: no change

1: little increase

2: large increase

For example, a farmer reporting that the amount of human labor used to farm millet did not change from 2008 to 2009, would be assessed as a 0. We computed total changes in these factors for each farmer by summing the changes across all four crops.

6.1.3 Demographic Information

We also collected data on several demographic variables including the farmer's age, gender, years of schooling, and neighborhood within the village.

6.2 Results

Surveys were collected from 73 farmers. Four farmers were excluded from the analysis due to concerns about the accuracy of the data. Two additional farmers were excluded after identifying these cases as extreme outliers.

The means and standard deviations of all variables are provided in Table 1 in the appendix for both groups. The average total crop production for farmers in the comparison group declined from 2008 to 2009 by approximately two bags, while the average production for Talking Book users increased by approximately three bags. Paired sample t-tests showed the Talking Book group significantly increased total crop production ($t[28] = 3.79$, $p < 0.01$) from 2008 to 2009.

Independent t-tests show that there are no significant differences in the 2008 crop production reported by farmers between the comparison and treatment groups. This suggests that the two groups were not different in terms of crop production prior to the intervention. We also found no significant difference between the groups in education, gender, or geographic region. However, farmers in the treatment group were younger on average than farmers in the comparison group ($t[61] = 2.21$, $p < .05$). This is consistent with our qualitative research, which showed younger residents were more likely to check out the devices.

[1] A bag can contain approximately 190 liters of crops.

Lastly, the difference between the groups on Change in Pesticide Use across All Crops was very close to significance [t(60) = -1.90, p = .06]. At a marginal level of significance, Talking Book users increased their use of pesticides from 2008 to 2009 more than non-users. This provides limited evidence that the recordings on the Talking Book explaining the importance of pesticides made a difference in pesticide use for farmers in the treatment group.

The standard deviations reported in Table 1 for 2008 and 2009 crop production indicate there is significant variance across farmers within both comparison and treatment groups. This is not surprising since a number of farmer-specific factors impact crop production each year. Therefore, to control for this farmer-specific variance, we compared the two groups using an Analysis of Covariance (ANCOVA) with total crop production in 2008 as a covariate in a standard pretest-posttest design. The results in Table 2, in the appendix, show that exposure to information on the Talking Book significantly increased total crop production in 2009 ($F = 13.48$, $p < .001$) after controlling for crop production in 2008.

Overall, this analysis suggests that the Talking Book had a significant impact on crop production.

6.2.1 Regression Analysis for Total Crop Production

To understand how large of an impact the Talking Book had on crop production relative to other measured variables, Table 2 provides regression estimates with Total Crop Production 2009 as the dependent variable while controlling for the effects of Crop Production 2008, Region, Gender, Age, Number of Years of Schooling, changes in human labor, changes in animal labor, and changes in land use. Crop Production 2008 is a significant ($B = 0.80$, $p < .001$) predictor of crop production in 2009. None of the other control variables are significant. Access to Talking Book Information is a significant ($B = 2.75$, $p < .05$) predictor of total crop production in 2009 after controlling for all of the other factors.

These results suggest that–after controlling for the effects of 2008 total production, changes in human labor, changes in animal labor, changes in land use, the age of farmers, the number of years of schooling, the region, and gender–farmers with access to information from the Talking Book produced 2.75 additional bags of crops compared to non-users. The approximate value of these additional bags was $89, based on market prices at the time of the survey (just after harvest, at relatively low prices). This represents, on average, an 18% increase in overall crop production for 2009. However, for many farmers in the Talking Book group, an additional 2.75 bags represents a lot more than an 18% increase.

Figure 5 shows the Percent Change in Total Crop Production from 2008 to 2009 for each group. Talking Book users had an average percentage increase in total crop production of 48% compared to a decrease of 5% for non-users.

For robustness checks, we tested a range of different model specifications. The results are the same if the dependent variable is Difference in Production across All Crops or Percentage Change in Production across All Crops (between 2008 and 2009). We also left Change in Pesticide Use and Change in Fertilizer Use out of the analysis because, as discussed above, some messages recommended increasing the use of these factors and significantly impacted the use of pesticides. Robustness checks including these two factors in the models did not impact the results. We also replaced the summation factors for Change in Human Labor, Change in Animal Labor, and Change in Land Use with values of the factors weighted by 2009 crop production. Again, the results were exactly the same.

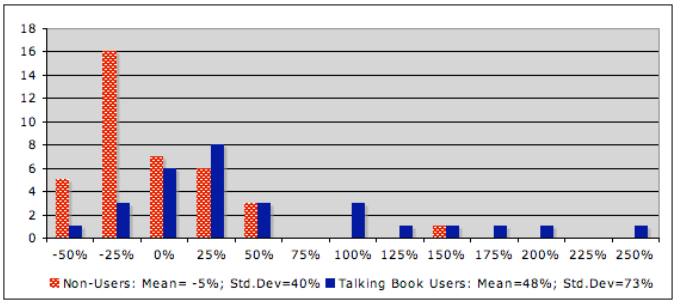

Figure 5. Comparing Users and Non-Users by distribution of Percentage Change of All Crops from 2008 to 2009

6.2.2 Excluding Extreme Changes in Input Factors

Given the limitations of our measures for changes in farming practices and inputs from 2008 to 2009, we ran the regression analysis again after excluding extreme changes in input factors. For each farmer, we removed any millet, maize, beans, or groundnuts crop production associated with either a large increase (+2 on our scale) or large decrease (-2 on our scale) in an associated input factor. This robustness check tests the effect of access to Talking Book information in the absence of any substantial changes in human labor, land farmed, animal labor, use of pesticides, or fertilizer use.

The results are nearly identical to the prior analysis. Talking Book users harvested 2.49 additional bags crops in 2009 compared with non-users after controlling for all of the other factors discussed previously.

6.3 Limitations

6.3.1 Selection Bias

The biggest limitation to these results is that Talking Books were not randomly allocated to users; instead farmers opted-in to the treatment group by checking out devices from the leadership committee. Therefore, Talking Book users and non-users may have differed in unobserved ways that impacted their change in harvests from 2008 to 2009.

We found no significant difference in 2008 crop production between the groups, but farmers who chose to use Talking Books may have been more motivated that year to improve their crops relative to farmers in the comparison group. Strong motivation might have led to more care and effort put into any farming practice. If this was the case, improvements made by our treatment group might not fully transfer to a less motivated group.

Due to the allocation issues mentioned earlier, it is also possible that farmers who checked out the devices had more resources than farmers in the comparison group. If this was the case, Talking Book users may have been better able to implement some of the recommended practices. For example, they may have owned more animals to produce more manure or had more discretionary income to purchase fertilizer or rent an animal to plow lanes.

6.3.2 Categorical Measurement of Other Potential Influences

Our measures of changes in farming practices and input factors were not ideal. We found no significant difference between Talking Book users and non-users with respect to changes in various inputs, aside from the marginal significance for Change in

Pesticide Use across All Crops. However, the categorical and subjective measurement of these factors ("no change", "large increase", "little increase", "large decrease", and "little decrease") may have masked the role of these factors. This imprecision and the small sample size may explain why none of the changes in input factors were found to significantly correlate with a change in production. More precise and objective measures would improve understanding of the relative contribution of these factors (e.g., surveying land use by measuring hectares for each crop planted in each year).

6.3.3 Self-Reporting Inaccuracies and Biases

The data from this evaluation was reported by farmers who may not have accurately recalled their 2008 production or precisely measured 2009 production. Because Literacy Bridge staff conducted interviews, Talking Book users may have been more inclined to report improvement. The presence of a local committee leader during each interview should have prevented patently false reports but may not have mitigated small exaggerations intended to please the interviewers.

7. DISCUSSION

In evaluating the potential of the Talking Book program to improve productivity of farmers throughout the poorest regions of the world, we consider three questions: 1) Is it effective? 2) Is it accessible to all groups? And 3) Is it financially sustainable?

7.1 Effectiveness: Talking Books Can Lead to Behavior Change

A farmer's ability to recite the details of what they listened to showed that they were using the Talking Book to *learn new information*. In our post-harvest survey, 91% of farmers using Talking Books in their homes reported to have *applied the guidance*. Further support that farmers learned and applied the information is provided by the significant *improvement in their crop production*. Our quantitative measurements lack precision and may have been influenced by selection bias and unobserved factors, but the results appear to support the qualitative feedback from farmers. Given these three outputs of our program (learning, application, and resulting production), we believe the Talking Book serves as an effective conduit through which illiterate residents in remote villages can learn and apply new health and agriculture practices.

7.2 Accessibility: The Program and Device Require Work to Reach All Groups

From the beginning, Literacy Bridge designed the Talking Book to be accessible to people facing significant challenges such as illiteracy, visual disability, lack of electricity, and extreme poverty. While it succeeds to varying degrees in bypassing these challenges, our program requires improvements.

Although most users comfortably operated the device after training, some of the least educated users still had difficulty. Usability improvements are important to reduce training time and ensure that the built-in audio instructions serve the needs of the least educated users.

To improve equitable access, we prefer replacing the checkout approach with a "household rotation" method. Each household will have a Talking Book for one week, after which the device will rotate to nearby neighbors and eventually return. Based on feedback from users, we believe this will improve access to those who are female, elderly, less educated, or otherwise marginalized. We will also continue to emphasize that users should not be afraid of damaging the device, a concern that impeded use for those with the least education.

Women and elderly residents were the least likely to use the Talking Book. It seems Literacy Bridge's steps to increase diversity on the committee may not have been adequate. Some residents assumed the devices were intended for educated young men, as represented by the committee leaders. In the future, we will make a greater attempt to ensure the most visible leaders of the committee reflect a more complete cross section of the village. That said, overcoming existing social structures within communities, particularly for women, will be challenging going forward. For example, in future pilots if batteries are not provided, this could disproportionately hurt women whose husbands manage household finances [19]. Furthermore, although a household rotation method could increase women's access to Talking Books, we cannot assume that devices will be shared equally within the home [26]. Increasing women's access to these devices will be important as this project develops, because while women play an active role in farming in rural areas, they are often excluded from extension services [27].

7.3 Sustainability: Return on Investment is Promising

The cost of the pilot program (devices, training, support, transportation, and batteries) was approximately $2480, but with the current Talking Book price at $35, the same program now costs approximately $1000. A conservative estimate shows that Talking Book use correlated with $2946 of crop value[2], a return of nearly three times the current investment within one season. If the same practices are applied in future years, the return on the original investment will continue to accrue.

75% of farmers expected to sell their surplus at a local market and many of those planned to use the cash to invest in agriculture inputs like seeds, animals, and labor. Other plans for cash from sale of surplus included payment of health insurance, home improvements, and school fees.

However, crop value does not equate to net income; we have not factored in transportation costs to get the extra crops to a market or the opportunity costs of marketing and selling the extra crops instead of any other alternative use of time.

These numbers indicate that the Talking Book can be a cost-effective intervention to NGOs and government organizations. The alternative for an agriculture extension office may cost an average of $20 to $30 each time an agent visits a rural village[3], which does not allow residents to reference the information when the need it.

Literacy Bridge aims to reduce manufacturing costs and profitably sell Talking Books for $12 to rural farmers. However, achieving mass consumer sales will require much more than engineering

[2] Calculated from: $32.46 (weighted average of price per bag at deflated post-harvest prices) x 2.75 bags (attributed to Talking Books in regression) x 33 farms (reporting having applied Talking Book guidance).

[3] Based on a single agriculture extension agent covering 40 village visits in one month for a monthly salary of $530 (typical for this district) plus fuel.

innovation and a compelling return on investment. Non-ICT investments are needed, such as a rural marketing strategy, development of sales channels into local markets, incentives for content creation (including entertaining content), and local enterprises to support and repair devices. In addition, to address the cash flow realities of the poorest farmers, business models providing rental or rent-to-own options might be necessary.

8. FUTURE WORK

Some of the questions we would like to explore include:

- What is the optimal number of devices per community and what is the best allocation method to reach maximum benefit? How does the type of access (in home, outside the home, word of mouth) impact behavior change?
- How does a user's social network impact trust and adoption? What is the impact of distributed peer comments about the agriculture and health messages?
- Is the device equally effective for men and women? What are the differences between genders and how can we close these gaps through program or devices changes?
- What types of information are most effectively conveyed in audio form to illiterate audiences?
- How can organizations learn from usage metrics, user ratings, and recorded feedback to improve their content?

We also believe there is an opportunity to leverage other related technology projects to enhance the impact of the Talking Book. For example:

- Talking Books can leverage existing mobile networks to improve content distribution to and from remote areas.
- Talking Books can equip infomediaries with detailed information and the ability to collect verbal feedback.
- Talking Books can serve regions without community radio (CR), share content with CR, and complement existing CR efforts by collecting listener stories and feedback.
- Future Talking Books will allow remotely programmed recording of any radio broadcast without user interaction. This may provide a cost-effective means of regional content distribution depending on the density of devices and the fee charged for airtime by commercial or community radio stations during the cheapest available timeslot.

9. CONCLUSION

This report presented the results of the Talking Book pilot study in the Upper West Region of Ghana. The goal of this pilot was to evaluate the impact of giving rural people access to locally relevant guidance—information they could listen to repeatedly and when they need it.

Residents showed great interest in the devices and were able to learn how to use them. Learning to use the device was generally easier for those with more education. Some were intimidated by the device's complexity, but our research suggests that this could be reduced with strong support from peers. Collaborating with local authorities to build buy-in was critical to success as was having a strong leader to monitor program implementation. Equitable allocation was a challenge because the devices became quite valuable—an issue that is likely to reoccur when devices are shared amongst a community. Future programs should make adjustments to broaden awareness of the program and to ensure women, the elderly, and other marginalized groups have more access.

We found that 91% of farmers who checked out Talking Books 1) learned the health and agriculture information provided by familiar local sources, 2) trusted the information, and 3) applied what they learned. Although there are limitations in our quantitative research, Talking Book users also reported significantly improved productivity relative to non-users. Collectively, our evaluation shows that on-demand access to information can considerably impact the lives of rural, illiterate communities. Furthermore, the Talking Book appears to be a cost-effective tool to enable learning and behavior change.

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11. APPENDIX

TABLE I
DESCRIPTIVE STATISTICS OF THE COMPARISON AND TREATMENT GROUPS

	Comparison Group			Talking Book Group		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
Crop Production 2008	38	17.01	16.05	29	13.80	10.10
Crop Production 2009	38	15.16	13.64	29	16.66	10.03
Δ Crop Production	38	-1.85	5.81	29	2.85	4.05
Percentage Change in Crop Production	38	-0.05	0.40	29	0.48	0.73
Δ Human Labor across All Crops	35	3.20	3.60	27	2.74	2.58
Δ Animal Labor across All Crops	35	0.57	1.79	27	0.74	1.26
Δ Pesticide Use across All Crops	35	0.46	0.85	27	0.89	0.93
Δ Fertilizer Use across All Crops	35	0.34	1.00	27	0.37	0.97
Δ Land Use across All Crops	35	1.31	3.92	27	1.56	2.45
Gender (0 = Male; 1 = Female)	38	0.13	0.34	29	0.14	0.35
Age	35	45.34	15.85	28	37.07	13.22
Number of Years of Schooling	32	0.88	2.15	25	1.68	3.11

TABLE II
REGRESSION ESTIMATES FOR ALL CROPS PRODUCTION 2009

Variables	**Model**
Intercept	2.67 (3.52)
Region1	-0.28 (1.75)
Region2	-0.74 (1.60)
Gender	2.09 (1.87)
Age	-0.07 (0.05)
Number of Years of Schooling	0.09 (0.30)
Crop Production 2008	0.80*** (0.06)
Δ Human Labor across All Crops	0.14 (0.24)
Δ Animal Labor across All Crops	0.42 (0.57)
Δ Land Use across All Crops	0.16 (0.22)
Talking Book Information	2.75* (1.35)
N	57
df	46
F	36.72***
Adjusted R^2	0.86

Notes: Unstandardized coefficients with standard errors in parentheses.

* p < .05 ** p < .01 *** p < .001