1. Problem Identification

What serious problem or challenge with broad significance does your use of technology address? Explain your context and the existing conditions that you are trying to improve or rectify.

Our organization works in the northern Indian state of Uttar Pradesh, one of the poorest states in India. The area is predominantly rural and has for centuries been plagued by abject poverty. In both education and health care, we face similar challenges. Most of the well-trained and qualified professionals, such as teachers, doctors, and public health workers are in cities. Rural teachers tend to lack knowledge and training; rural residents and front-line health workers lack access to even the most basic health care information. Those who do work in rural and remote areas are physically isolated from each other; it’s difficult for them to share grassroots wisdom and experiences with each other.

For schools, in addition to lacking training, rural school teachers have to cope with difficult social economic issues such as child labor, child marriage, gender bias, and caste bias. Many schools are in remote areas; and many of those are single-teacher schools. Without the support of a larger community, these teachers often feel overwhelmed by seemingly unsurmountable adversities that represent forces so much larger than themselves. It's understandable that often a sense of frustration, isolation, and hopelessness can set in at such a place.

In terms of health, high birth rates and high infant mortality rates are the norm. A clinic or hospital is often far away. Transportation is difficult to arrange. Villagers are concerned about being charged a high fee that they can't afford if they seek care. A conservative culture dictates that most do not feel comfortable about the idea of a woman traveling alone (to seek care) without the company of a male relative, who is often needed in the field or at other work places (like a brick factory) from dusk to dawn. People tend to overlook questions or minor illnesses until problems appear to be getting serious; they often seek advice from local quacks, who typically end up doing more harm than good. One of the local traditions is to smear cow dung on a recently cut umbilical cord; another example is the custom of cutting the umbilical cord exclusively to low-caste helpers, and when such helpers need to be fetched from afar, the umbilical cord remains attached for as long as 24 to 48 hours, worsening infection rates. Many of these customs and misconceptions are not necessarily widely known or practiced elsewhere so one-size-fits-all "expert" broadcasts or pamphlets rarely adequately address such misconceptions. Easy and regular access to small morsels of relevant information would help in preventing and identifying small problems and bad practices before they develop into something far worse.

How does one go about the business of better connecting rural teachers, residents, and front-line health workers to knowledgeable professionals in cities? One naive thought is this: let's just give out phone numbers of expert teachers and doctors. Even in the poorest areas, luckily, simple mobile phones are widely available and voice signal coverage is good. If a rural teacher or a rural resident has a question of any kind, perhaps she can just call up an expert in the city. This naive idea doesn't quite work. While there's tremendous grassroots volunteer-ism, few would be willing to hand out
personal phone numbers like this. "Call centers" or "hot lines" don't work well either. Knowledgeable urban professionals are busy people and they seldom have the required dedicated big chunks of time to, for example, commute to a call office and wait for incoming calls, which may or may not even be relevant when they do come.

Old fashioned one-to-one phone conversations have other limitations. A good exchange, ideally, should benefit a larger audience than just a single caller once. The information should be somehow "saved" and reusable. Expert "bandwidth" is a precious resource, whose utility can be significantly amplified with judicious organization and re-use of prior exchanges. Also, when dialing a particular number, a questioner could be directing her question to the wrong person, who for various reasons may not be in the best position to answer it. It would have been better if questions are addressed to a "forum" or large "panels" of potential responders, who can self-manage or be better coordinated in deciding who should respond to what when, based on their expertise, interests, experiences, time availability, and other factors. Simple phone calls just don't allow any of that.

There have been various attempts of deploying some sort of net-based technology in rural areas to address issues such as these: kiosks equipped with networked computers, or smart-phone-based solutions, to name just two. The practicality of such solutions is limited in the kind of environment that we work, due to cost, usability, and infrastructural issues, such as lack of electricity to power a kiosk, lack of land-line connectivity, lack of wireless data network coverage--while voice coverage is pervasive, data coverage is far from ubiquitous. The low literacy rates of the community that we serve further compounds the difficulty of these existing technology-based solutions. Our experience is that even an SMS-based solution, for example, is difficult to make work in this environment. Simple voice phones are all people can afford, already have, and feel comfortable using.

2. Description of Technology Application

Fully describe the technology application. What technology is being used? How is it being used? Who is responsible? Who is benefiting? What processes or systems are in place to deliver this technology application?

We have built two voice forums: one is a teachers' forum, and the other connects rural residents to doctors and health workers. They share a common underlying infrastructure but also contain significant differences. On any given day, hundreds of teachers, villagers, and doctors use these pilot voice systems to communicate with each other. In the process of building the voice forums, we have also developed a hardware and software framework that we believe have wider applicability for other similar community efforts. As we shall explain later, technology-wise, our system is very different from how voice applications (such as the excellent Lifelines system, an earlier laureate) have been traditionally constructed and our approach provides important advantages that the traditional approach cannot match.

The teachers’ voice forum connects rural teachers with their more skilled counterparts in cities and with peers elsewhere. Teachers use simple voice phones to access the system. They hear messages recorded earlier by others and record their own to be heard by others later. All messages are stored in a digital voice database. They leave textbook-related questions, report logistics-related problems (such as scratched DVDs distributed by the larger Digital StudyHall video-sharing program run by us), seek advice, receive feedback, share experiences, conduct remote student and teacher activities (such as science question competitions, poem and song competitions), vent frustrations, offer answers and solutions to others, and, very often, provide a much needed remote pat-on-
the-back to those who, against all odds, have done well. In addition to teachers, hundreds of trainees from the regional teacher training colleges participate in the voice forum as well: the forum allows the trainees, who traditionally have been disconnected from the real-world schools during their training, to better understand the ground reality. For all the participants, the voice forum acts as a vibrant "virtual community" for teachers, buzzing with excited chatters at all hours: like a popular Internet "chat room," the system never needs to sleep.

The voice forum doesn't just address school subject matters; it also deals with all manners of social economic questions that sometimes are taboo subjects. For example, on 10/20/2009, Shazia Khan, a teacher form the SEWA school, said: "Girls as young as twelve years old in my school get married off. This is wrong. When I hear this, I visit the girls' families and talk to the parents to try to stop or delay the marriages. I think all the teachers should do this." Among the many enthusiastic respondents, on 11/03/2009, Sharda Singh, a teacher from the Madantooosi school, said, "Yes, girl students are treated unfairly. Parents tell us that girls need to help in the field during harvest season; otherwise, they say, they will starve. But parents are much less likely to say the same thing about boys." This lively thread continues for about a month, with teachers from all the schools chiming in with their own experiences. Towards the end of the thread, Avanish Kumar Shukla, a teacher from the Gangaganj school, said on 12/16/09, "This discussion has been wonderful. This kind of conversation would never have occurred in our school or in our village if we hadn't heard it on the voice forum." (See many more examples on a voice server mirror at http://dsh.cs.washington.edu/info/voice_database.html.) About 15% to 20% of the participant teachers are active contributors; the rest are "lurkers"--they listen diligently but rarely speak up. This is not unexpected--one of the intended purposes of the system is to get some of the more passive and less progressive participants to learn from the more proactive "leaders," for without the voice forum, it's not easy for someone in, say, a one-teacher school in the middle of nowhere to have role models to look up to.

In our second voice forum, the doctors' forum, the voice system and its associated voice database allow under-served villagers to post health-related questions that are asynchronously answered by panels of volunteer doctors and other healthcare workers. Villagers leave their personal queries, receive timely and relevant personal responses, or receive broadcast messages (that are of general interest to larger groups). Staff of our partner NGOs and volunteer nurses administer the voice system via a web interface. They filter, categorize incoming questions and assign them to doctors of particular expertise and interests. Depending on their preferences, volunteer doctors receive their "assignments" via a phone interface, or a web interface, or in email; and they may respond via any of these means. For example, some doctors prefer to listen to incoming villager questions that are sent to their email addresses but they prefer to reply via a phone interface by calling back the voice system. Once the voice system receives the doctors' replies, it schedules outgoing reply calls to the villagers who have asked the questions. The cycle may repeat several times as doctors ask clarifying questions.

Doctors tend to be very busy people. The fact that the voice system allows them to contribute small bits of wisdom in an extremely flexible and convenient way is critical to our success--a doctor could instruct the system to call her once a week at a time of her choosing and she answers a couple questions read to her by the system. This is a far cry from the "heavy-duty" commitment of a call-center type arrangement. Many being socially progressive people, given the any-time (the system is available 24/7), any-place (home, office or even when they are traveling), any-device (computer, phone, or a mixture) convenience, the doctors that we have approached are far likely to agree to participate. The power of the system lies in its ability to harvest such small bits of contribution from many contributors and pool them together into a well-organized and cohesive authority and repository of knowledge.

We should point out that we intend the main role of the doctors' forum to be
informational and educational; it's about spreading awareness, combating superstitions and quacks, encouraging healthy practices. (For example, one of our main partner organizations specializes in HIV/AIDS awareness.) We don't intend the system to provide outright cures of urgent illnesses. Although villagers inevitably ask a wide variety of questions, many of which do involve potentially serious illnesses, our volunteer doctors, being the professionals that they are, are careful not to jump to rash conclusions. Often, they suggest possibilities and recommending follow-up checkups is the best course of action. Our hope is that regular access to authoritative information sources can play important preventative roles before things get much worse. Having said that, we have already begun to integrate our voice system with partner organizations that run physical outreach programs so that, for example, regular van trips drop off medicines or pick up patients for further checkups, activities that the partners are already engaged in but could be made more effective.

In addition to sharing the underlying hardware and software infrastructure, the teachers' forum and doctors' forum also share important philosophical themes. One of the themes is sharing: the forums enable more than mere one-to-one conversations. In the teachers' forum, a physically isolated teacher, being able to hear and speak to many others like herself, may feel that she is constantly a part of a larger caring virtual community, a community that shares and understands her problems and frustrations, a community that is eager to speak up to offer timely and relevant advice. Similarly, in the doctors' forum, if a forum administrator (a staff of an NGO) feels that certain exchanges may be of interest to a larger group, such as a pregnant women's interest group, with appropriate anonymizing, the administrator may "narrow-cast" an edited version of the exchange to the group. What's being accomplished here is a kind of "network effect:" the power of the system is much more than the mere sum of individual one-to-one exchanges--we begin to reap the benefits of a "crossbar switch" that enables many-to-many and all-to-all exchanges.

At this point of the discussion, although a reader of this submission may get a sense that the voice forums that we have built are functionally useful, he or she may think that, technically, this is just like IVRs (Interactive Voice Response systems, such as the ones that banking customers experience when they dial a 1-800 number). In our answer to the next question, however, we will explain that due to the very different environment, target audience, and application requirements that we must work with, the technical challenges and solutions that we have had to work on are also strikingly different from those of traditional IVR systems.

3. Explanation of Leading Edge or Breakthrough Technology

*Why do you think that your use of technology is worthy of recognition? Describe if it is a new technology or a new use of an existing technology. How can it be distinguished from existing uses? Explain how it surpasses previous or current solutions.*

Traditionally, voice systems that may be deemed similar to ours (such as the excellent "Lifelines" system) are typically developed with expensive proprietary PBX equipment and software, often with the blessing of carriers. In the case of Lifelines, the excellent agricultural question and answer system, for example, British Telecom provides the proprietary hardware and software (developed by a software team put together by BT). The system runs inside the BT infrastructure; only the call-center-like staff sit at the periphery; everything else is sanctioned, managed, and executed by BT.

To understand why this arrangement is a severe limitation, consider the following analogy. You're the web master of a small NGO. You would like to put up a web site to
tell the world about your organization. In addition to simple static pages, you may have a couple simple scripts to allow visitors to leave comments or receive newsletters. Unfortunately, to start you must be sanctioned by a big phone company. They would want to know what the site is for, how many visitors you might have, how much money you are willing to pay (or why they should donate significant resources of their own to your organization). If the phone company deems your organization unworthy, you are out of luck. If you're the lucky few that the phone company have decided to bless, they will put together a team to build the site for you; it won't be cheap. They will house the equipment to serve the site for you; it won't be cheap. Once it's done, it's done; if you want to make changes, you will have to ask the phone company's software team to make the changes for you and it won't be cheap. The changes, should you brave to make them, will take time. (Large organizations sometimes can afford to recreate much of what the phone company does in terms of building a sophisticated PBX application, but the basic mode is the same.)

If this is how the web works, there would never have been a web! There is a direct analogy between a web server (WS) and a voice server (VS). There's the application-specific code: cgi-bin scripts on a WS, and its equivalent on a VS. There's the common infrastructural code: the Apache server and its friends running a WS, and an equivalent low-level voice software stack on a VS. There's the hardware: regular PCs and network interface for a WS, and the equivalent phone interface hardware for a VS. On a WS, every piece mentioned above is open: anyone can do it easily and cheaply; that's why the web as we know and love has flourished! On a VS typified by what British Telecom has built, none of the above is open to the public, which is unfortunate. Had the "ecosystem" been open and easy for people to take advantage of, we could have many more voice applications, constructed by diverse organizations and individuals, big and small, benefiting under-served populations, for many of whom simple voice phones are their only practical link to a bigger world.

In summary, the traditional proprietary approach of constructing voice applications, in a closed eco-system, is costly, difficult to customize, and difficult to justify for small groups of targeted users.

In contrast, our system is built on top of cheap ISDN line cards plugged into conventional PCs and the open-source Asterisk framework. The voice servers simply sit in our regional offices, as opposed to being locked inside telecom carriers' machine room closets. The software that we wrote to build the two forums consists of about 22,000 lines of Python code. The existing low-level frameworks (such as Asterisk), however, are not for the faint-hearted; part of what we have done is having built additional software components on top so that the task of building a certain class of similar database-driven voice application in the future is drastically simplified. Using this method, we were able to quickly build two sophisticated voice forums, the teachers' forum, whose predominant mode of exchange is all-to-all sharing, and the doctors' forum, whose predominant mode of exchange constitutes a so-called "bipartite graph." Our experience has been that voice applications for different contexts are very different and one-size-fits-all attempts cannot work well. What our system allows one to do is to quickly and easily build these different voice systems, just like the Apache web server allows users to quickly and easily build web sites, without worrying about the low-level details.

The decentralized and open approach is low-cost, provides extreme ease of local customization, and makes it feasible for us to experiment with tailor-made solutions for small local populations and organizations. We don't need phone company blessing. The solution can be easily and cheaply replicated at many locations, and because these distributed systems are networked, the information can be easily shared across the entire network of voice servers.

We are not the only ones who have realized the tremendous power of the approach of decentralized voice applications; this was exactly the kind of power that the inventors of
the Asterisk framework envisioned in the late 90s when the hackers wanted to wrest the freedom of telephony tinkering from the all-powerful phone companies, and there are other budding efforts that are beginning to take advantage of Asterisk in developing world settings. Part of our contribution that sets our effort apart is that by building and deploying two substantial voice applications for the developing world context using this technology, one for education and one for health (whose functions and features, to the best of our knowledge, are unique), and the underlying enabling common components, over an extensive period of continuous field work, we have had to develop a large number of innovations that are necessitated by the unique challenges of our target environment. We next discuss some of these unique innovations.

(1) Menu-less client operations driven by "stateful" servers. In a traditional IVR, a user is forced to navigate a hierarchical voice menu: "press 1 for x, press 2 for y." We have found that this is a level of confusion that our rural users don't want to or can't cope with. Instead, our teachers use a simple menu-less interface: they hear a sequence of messages and they get to record a message of their own; that's it! This client simplicity is hiding a level of sophistication on the voice servers: because the voice server "knows" who the caller is and her entire call history, the voice server employs heuristic rules to decide what to play. Similarly, when a volunteer doctor is read a villager question by the system, the doctor sometimes needs some thinking time before she can formulate a response so she hangs up. When the doctor calls back later, the voice server "remembers" what this doctor has and has not done so it continues from where it left off. In a sense, the interface "intelligence" is moved into the "cloud," or the "stateful" servers, where far richer data in the voice database is used to make good decisions.

(2) Auto-dialed outgoing call schedules. Villagers earn so little that the cost of making a single call to the forum is a burden. Luckily, receiving calls in India is free. If our voice forum "spams" a villager blindly, however, the system could catch a callee at a bad time and we have found that not to work either. Instead, villagers get to specify at what time they wish to be called by the voice server and they can change their preferences. The voice server manages the call schedules and uses various heuristics, such as the type of message waiting to be heard, to decide when to automatically dial a village phone. This approach has proved particularly popular!

(3) Listener interest groups. For example, in the teachers' forum, the teacher training college trainees form their own interest group and share their own messages. The doctors' forum supports interest groups formed among pregnant women and among women with young children, so the forum can auto-dial them with regular reminders concerning maternal health specifics.

(4) Network integration. While villagers access the voice forums with simple voice phones, others (including staff, urban teachers, education experts, doctors) have the option of accessing the forums through a web interface, served by one of our voice server mirrors. The mirrors synchronize with each other to present a coherent view. Our collaborators at the education schools of University of Washington Seattle and University of California Berkeley, and US-based doctors access the forums via a US-based voice server mirror. The voice servers provide VOIP features that allow these remote participants to contribute easily.

(5) Shared phone devices in the field. We have placed "phone radio boxes" in some of our schools: these are phone boxes that are equipped with amplified speakers, powered microphones, and their own power supply. They allow student group activities such as singing, science question, and poetry reading competitions; They also allow interest groups of the doctors' forum to hear messages together and discuss among themselves.

(6) "Remote-controlling" voice servers from the field. Field staff of our partner organizations demonstrate usage of voice forums in villages. During the demonstrations, they need to instruct the voice server to perform certain operations in real time. Initially,
we had to use laptops equipped with 3G wireless data cards for this. This is not the best way: laptops are expensive, hard to learn for field staff, and the 3G data coverage is spotty at best. Since we realized the initial difficulties, new code has been added to the voice servers that allows them to be "remote-controlled" by simple voice phones operated by our field staff.

(7) Sophisticated voice database features including indexing, searching, advanced queries, history-threading, key word tagging, usage history data mining, and much more.

4. Evidence of Contribution

How do you know that your application of technology is having a beneficial impact? Please provide data or evidence to support your claims.

Field deployment and testing of the teachers' forum in the state of Uttar Pradesh (one of the poorest states in India) started in September of 2009 (although spotty smaller experiments had been going on much earlier). We have seen time and again that our initial assumptions and designs often proven flawed. New requirements are being continuously gathered from field testing, and newly implemented features and changes are immediately rolled out for field trials.

We have gradually added teachers and schools in the months since. As of April of 2010, the teachers' voice forum prototype has about 300 teacher users, spread across 35 schools. The system has logged a total of about 3,700 calls, lasting about a total of 8,000 minutes. About one fifth of these have been new messages recorded. (In all the figures that we report, we only count the "real" calls--mistakes or silence due to operator errors are not counted.)

To hear (or read) some of these messages, please visit this voice server mirror:

http://dsh.cs.washington.edu:8080/admin/db/item/?starred__exact=1

The full voice database administration interface can be accessed at this mirror page:

http://dsh.cs.washington.edu:8080/admin/db/

The doctors' voice forum is newer: its deployment started in late January of 2010. Since mid-February, we have been steadily adding participating villages at the rate of roughly one or two villages per week, and volunteer doctors at the rate of roughly one or two per week. We handle about ten calls per village per week.

Potentially sensitive medical cases that we discuss below have been anonymized.

Obviously, the crude numbers above alone don't necessarily tell the whole story: yes, people do use the systems, but are the voice messages being shared meaningful? Below, we give some typical examples.

Earlier we have discussed the example of a teachers' conversation thread concerning child marriage and parents' neglecting girl children's education. We now give some more examples.

(1) During a discussion of strategies of making school more fun for students so that they enjoy coming to school, a suggestion was offered that more real-life examples could be used in classrooms. In response, teachers reported their own attempts. One said that
earlier she had to keep admonishing students who preferred to play with beads and marbles during classes; but now she tried incorporating marbles into many subject matters, such as arithmetic; it made a big difference in her classroom. (2) Each new semester, newly admitted students often lacked the backgrounds needed for their respective grades. Suggestions were sought and many were offered. One suggestion was to organize students into groups and to designate study "buddies" for those who were falling behind. (3) Immediately before and after major holidays, there had been severe student absenteeism. One teacher reported a successful scheme of organizing fun painting competitions at those periods to lure students back: the students who missed the classes regretted having done so. (4) There was a heated debate among government and private school teachers about the argument that government schools performed worse due to lack of accountability. Although little was resolved, the controversial discussion likely at least motivated some of the government school teachers to work better so they could live up to their own defensive arguments. (5) Envious of the student competitions organized on the voice forum, teachers clamored for a competition among themselves. An agreement was reached that there should be a teachers' poem competition and the poem entries would then be shared with students. It was a great creativity exercise and the resulting shared poems made teachers more approachable to their students. (6) Teachers agreed that most rural family parents didn't appear to take their children's education seriously and would rather put them (especially girls) into field work. Among the suggested action items were regular teacher visits to parents' houses and regular parent meetings at schools. One teacher reported that although many parents skipped such meetings, many did show up. Another teacher counseled patience: progress would take time so we should keep trying, she suggested. (7) One teacher said that students always tried to dodge test days. A suggestion was offered that students should be made aware that the low test scores were not meant to shame or punish them but tests would help teachers help them better. Hear some of these messages in teachers' own voices at the following link:

http://dsh.cs.washington.edu:8080/admin/db/item/?key_words__id__exact=29

The common theme in these examples is that teachers from isolated remote schools get to put their heads together, share problems, share solutions, share encouragements, and help each other. Perhaps one of the clearest signs that the teachers' voice forum has been helping is that during a few rare periods when the voice server was taken down due to various technical reasons, we got queries from anxious teachers who demanded to know why they hadn't received expected auto-dialed calls from the voice forum.

We now give some examples of messages exchanged on the doctors' forum. R is a girl from the village called Saraiyya. She's 18 years old and she records a message saying that she's been having stomach ache during periods. Dr. Abha Ashutosh is a gynecologist. She's available for receiving and answering questions from the doctors' forum everyday between six and eight in the evenings. For R's question, the doctor records a reply that says the questioner should have milk and exercise regularly. In case of excessive pain, she should take some anti-spasmodic drug (meftal spas). If she has white discharge too, she should get a checkup.

M is another lady from the same village. She records a message saying that she's been experiencing pain in her legs for the past year; at times they get numb while walking. Dr. Ashutosh Gupta is a surgeon but when he signed up to participate in the forum, he called himself a "jack of all trades" so he's available to answer many kinds of questions. He listens to questions left for him on the forum between seven and eight in the evenings. In response to M's question, Dr. Gupta says the problem could be due to one of two reasons. Either there is some obstruction in blood circulation, or some nerve is getting pressed in her lower back. We are likely to have more answers for her when we have an orthopedic doctor on the forum. Dr. Gupta says there are several tests that could ascertain the true cause. If possible, she should get a CT scan of waist and lower
back and vascular angiography of legs done.

These examples represent the most typical queries. They also illustrate several aspects of the system's operation. The volunteer doctors are admitted into our system with an informal word-of-mouth self-policing mechanism so that their credibility is vouched by peers. Being the responsible doctors that they are, they typically suggest several most likely possibilities and rarely jump to premature conclusions. These possibilities suggest the urgency of the situation and the doctors typically counsel further checkups. For something that's urgent, the doctors' urging of seeking immediate care is critical. For something that's less so, the doctors could suggest remedies such as adopting healthier habits, like diet changes. Many of these exchanges involve multiple back-and-forth question-answer iterations between villagers and doctors.

The voice forum also provides an opportunity to ask medical questions that are considered "taboo" in a conservative and religious society. For example, one lady asks for remedies for a particular sexual dysfunction of her husband, a question that she's unlikely to have asked without a degree of anonymity. As another example, even asking questions in public concerning HIV/AIDS could bring stigma and, in the worst case, result in the questioner being ostracized from peers. The role served by the voice forum is particularly valuable in such cases.

Both the villagers and the doctors who know the local conditions say that in the absence of such information, since the closest clinic to a village is typically at least tens of kilometers away and transportation is difficult to arrange, the villagers would routinely seek advice from local quacks, who could either suggest supposed remedies that are actually harmful, or offer nothing more than a placebo, which could inflict harm in its own way, because the placebo may delay a much needed real intervention. In the absence of the doctors' forum, when doctors that are part of local organizations' outreach programs do happen to physically visit a village, it's very typical that the whole village empties out to see the doctor, because this could be their only chance to see a real doctor for years (if not longer). There's almost a stampede, a sense of desperation. The voice forum provides a much needed constant trickle of small morsels of health-related information and we believe it serves an extremely valuable educational role.

5. Goals and Metrics

What are the long-term goals of your project, and how are, or will, you measure success? How are you reporting your results and to whom? To whom are you accountable?

In the long run, ultimately, we would like to see the teachers' voice forum contributing to student performance improvement, improved teacher skills and awareness of their responsibility in combating various types of biases that hinder learning. We would like to see the doctors' forum contributing to improvement in measurable public health metrics.

For both forums, there are some more direct statistics that can give us an indication of the success of the forums, such as the number of messages being exchanged on the forums, the number of participants, and the number of real-world activities that are instigated by exchanges on the forums. Perhaps more important than sheer quantity of messages is the quality of the messages. (We have attempted to convey a sense of the message quality, in terms of example issues that are addressed, in our answer to the previous question.)

Change in people's attitude, as a result of participating in the forums, which are really education mechanisms, is a little harder to measure, but possible to discern. For
example, on the teachers' forum, we see previously quiet teachers gradually speaking up more. We see the sophistication of the messages increasing over time as the more outspoken and progressive teachers lead the way. On the doctors' forum we will see people becoming better informed as a result of regularly receiving twitter-like voice messages that are beamed from the forum and designed to be parts of, for example, an HIV/AIDS knowledge campaign or a program designed for pregnant women; in the case of these particular examples, we may conduct pre- and post-tests among the target audience to gauge the effectiveness of the forum program.

Ultimately, we need to see "bottom-line" improvements. For the teachers' forum, this means student performance improvement, which we recognize requires a complex set of interventions that go beyond the teachers' voice forum. To this end, our organization conducts a variety of activities (one of which is a community video-sharing program that propagates the best teachers' classes on DVDs that are shared with needy schools, a program that was a Tech Awards laureate in 2008). Due to the complex interactions of the interventions, it is difficult to separate the individual contributions of the different activities. For example, the sum of the benefits of the video-sharing program and that of the teachers' voice forum, each in absence of the other, may very well be smaller than the total benefits of the two programs run together. So what we have been measuring and will continue to measure is the cumulative effects of our efforts. We conduct unit tests and quarterly tests and monitor the trajectory of overall student performance in the schools that we work with. In most of our schools, we are seeing a marked upward trend.

In addition to student performance, an important long-term metric is teachers' capacity improvement. One way of evaluating it is the following. In selected schools, our staff visits once a week, and during the visit, the staff films one or two live classroom sessions as a passive observer. The footage is brought back and, in collaboration with education experts from the University of Washington Seattle and the University of California Berkeley, we carefully analyze the footage to discern whether and how the classroom culture improves over time. To some extent, this classroom "culture shift" can be quantified. For example, during a six-month study of an English class, we observed that the average number of times students spoke up in English, an important indicator of whether the teacher has learned to adopt interactive methods and whether the teacher has understood the importance of building an immersive environment for teaching a new language, increased from an average of 17 times per class during the first three months to an average of 50 times per class during the last three months. (There are many other numbers involved in the study.)

Some of the schools that we work with are government schools and we report their results to the state government. The remainder of the schools are operated by various NGOs that we partner with and the results of these schools are reported to the partner NGOs and their boards.

We expect the doctors' forum to accumulate a large number and variety of messages, the analysis of which may yield valuable insights of how the system contributes to improving the well-being of questioners and how we may improve the system. For example, we may tally the number of times when a relatively minor condition, which could develop into something far worse if not dealt with early, is brought to attention of participants in the system. We may tally the number of times a questioner alters her behavior as a result of receiving information from the system. On the other hand, if the system fails to effect behavior change despite doctors' urging, we must analyze the causes and examine whether we could make changes to the system to make it more effective in similar cases. In the longer run, as we have discussed earlier, we are integrating the doctors' voice forum with partner organizations' existing outreach programs, and we will work with partner organizations to evaluate the effectiveness of such outreach programs.
Ultimately, as is the case with the teachers' forum, the doctors' forum must answer to ultimate "bottom-line" metrics. Examples of such metrics are infant mortality rates, maternal mortality rates, the incidence of polio, etc. We plan to work with public health experts and organizations to develop a long-term census program that's run on the voice system. This will not only track the effectiveness of the existing activities on the voice system, but also potentially open up new horizons of future innovative public health programs that can take advantage of the voice system platform.

**6. Description of Potential Negative or Unintended Consequences**

Describe any outcomes that may not be beneficial that you have considered. Who might consider your application problematic and why?

In answering this question, we explore several issues that are not necessarily "negative or unintended consequences," but more like potential conflicts or frictions, sometimes brought to our attention by external colleagues who might be less familiar with the details of our project.

One question about the doctors' voice forum is "what if the doctor's advice is wrong." We work in a society that has a long tradition of a social web of informal help. It's a part of the Ghandian legacy. Volunteerism is common practice. In absence of the technology platform we have provided, people have always sought and relied on support of an informal social network that can reach far and wide, largely by word-of-mouth. In that sense, the doctors' voice forum is nothing more than a natural extension of that tradition and spirit. The rural recipients of the advice are very much aware of the fact that the volunteer doctors are sacrificing their time to provide a social good for free and the recipients express nothing but gratitude. It's a far cry from the sometimes overly litigious culture that we see in the US.

The doctors in our system rarely provide unequivocal diagnosis; instead, when asked about certain symptoms, they typically suggest several likely causes, and if one of these could be a cause for serious concern, they counsel further checkups. This is a cautious mode of tentative informational prod that's highly unlikely to lead to accusations of mis-diagnosis, because the information being offered is not a "diagnosis" per se to begin with.

So far, we have admitted into the system only doctors that are vouched by peers. They practice in reputable hospitals. There can be no doubt about their qualifications or credentials. This approach of adding doctors by word of mouth may very well be adequate for the foreseeable future, although we have had speculative discussions on the future possibility of providing peer-review mechanisms among doctors.

Now we discuss a potential issue of the teachers' voice forum. Because some of the issues that we discuss on the teachers' forum are socially progressive and run against the social norm, there is the question of whether the rural teachers are receptive to such messages, and whether such messages may generate friction between the schools and the communities within which they operate. Some example controversial issues are child marriage, child labor, girl children's education, and caste issues.

Our experience has been that the participating teachers are overwhelmingly receptive to these messages. They see the unfairness and hindrance to their work first hand. Even if some of them have not spoken up in the past, the voice forum has provided to them a first opportunity to do so. There have been times when there are disagreements among the teachers. What we have then is spirited debates. This is healthy. For example, during a discussion on the problem of girl child marriage, some feel that perhaps the institution
of marriage itself is being bad-mouthed and they feel compelled to defend it. This leads
to a spirited discussion on what a girl could gain by staying longer in school and delaying
marriage--marriage ends schooling because wives are expected to stay home to do
housework, and the girls themselves uniformly do not want to leave school to get
married. The more experienced and progressive teachers point out that the benefits of
extra schooling are not necessarily about skills that could immediately get them jobs: it's
about building self-esteem and self-confidence, gaining can-do problem-solving
experience, seeing possibilities of what they could accomplish, gaining a life outlook of a
broadened horizon that can benefit them for whatever may greet them for the rest of
their lives. This is an example of somewhat controversial topics, feeding on people's
passion in their opinions, eventually leading to a valuable educational experience for the
entire audience of the forum, including the quiet lurkers, who may have harbored
opinions that are similar to some of those that have been voiced. These are the kind of
messages that the teachers need to hear from their peers, not from some "outsider"
giving a "sermon."

While some of the topics could generate some controversy on the teachers' forum, the
parents and the community at large are generally less receptive to some of the
messages. This is not at all unexpected. Indeed, one of the purposes of the teachers'
voice forum is to encourage the teachers to spread the messages to parents during
occasions such as parent meetings and visits to students' homes.

7. Discussion of Replication Potential

Describe how your work might be a model for others to emulate. Could this
application be put to use in other places or contexts?

There are two different possible levels of replication. At one level, we may talk about
replicating the teachers' and doctors' voice forums. At another level, we may talk about
using the voice platform that we have developed to construct other applications.

We believe the teachers' and doctors' voice forums have obvious applicability and, in
fact, fulfill urgent needs in many places, both in India and in other developing countries.
The problems that we target and have discussed earlier, that physically isolated rural
teachers need a virtual community for support, that rural residents desperately need a
channel for obtaining personalized and timely health-related information, are pervasive.
The demand is present and urgent. On the supply side, skilled professionals everywhere,
trained teachers and doctor volunteers in the case of our two voice forums, are eager
and ready to help. What they need is a mechanism that allows them to contribute in a
flexible way that doesn't require an unreasonably heavy burden on their busy schedules.
There are also many grassroots organizations that are willing to play the roles of
intermediaries if they are given the right tool. We believe such demands and supplies are
common in many places. The question is whether we can provide a mechanism to
connect the demands with the supplies in the neighborhood, a mechanism that can be
realized today, with existing resources in these neighborhoods. We believe that our
experience with our voice forums shows that the answer is yes.

Beyond the teachers' and doctors' forums, in our preliminary discussions with interested
NGOs, we speculate that the same voice platform can be adapted and customized for
other application contexts. The two examples that we have discussed are women's rights
(covering sub-issues such as domestic abuse, spouses' alcoholism, legal rights, livelihood
skills and opportunities, mother-daughter partnerships in education, and maternal
health) and small business opportunities (covering sub-issues such as skills and
experience sharing). One may think of these in terms of analogies such as forming
Usenet groups, starting and participating in chat rooms, or following twitter feeds, in
support of communities or interest groups, except we are using the ubiquitous voice phones to achieve similar effects.

Architecturally, the voice forums are structured so that they can be easily replicated. One does not need the blessing or permission of a phone company or anyone else. There is no mandatory centralized infrastructure (such as centrally-run voice servers or phone equipment), although sharing voice server equipment remains an option. Again, a useful analogy is to think of these voice servers as web servers that can be independently set up, shared if desired, customized for different purposes, and all networked together so their data can be shared. Such a network of voice servers can then constitute a "voice web," providing a variety of diverse services, run by a diverse set of organizations, catering to those whose most sensible access to information is via simple voice phones.

In terms of hardware components, the system is cheap and easy to replicate. Unlike expensive proprietary PBX equipment, the phone interface hardware is simple ISDN line cards. The voice servers are regular PCs; machines that are several years old typically suffice. An "ISDN BRI line," allowing enough calls to sustain one of our forums, can be had for less than $20 a month in India. One can begin experimenting on an existing old PC--if the experiment fails, the PC reverts back to its old role and not much is wasted. If the call volume happens to grow beyond what one phone line, one interface card, or one PC is able to sustain, one can gradually and easily add phone lines, interface cards, PCs (in that order). Such graceful incremental scale-up is far cheaper and far easier to manage than having to purchase expensive, dedicated, special-purpose, heavy-weight, proprietary PBX equipment that does not come in small increments and has no other use if the initial experiment fails.

From the point of view of end users, at least in terms of equipment, the replication story is even simpler. Unlike approaches that require the extensive deployment of computers or smart phones, which are expensive, difficult for our audience to learn to use, and largely impractical in the environments that we target, the voice forums require no more than simple ("dumb") voice phones, which almost everyone already has. (They are typically not personal phones but shared "family phones.") The voice forums require only cellular voice signal coverage, which in our experience so far, has been available literally everywhere we've been to in rural India. Cellular data signal coverage required by conventional Internet-based approaches, on the other hand, has been difficult to come by in rural areas.

The voice forum approach is also ripe for replication from an organizational point of view: individual NGOs, specializing in various fields, can easily roll their own voice servers using the platform that we have developed, play intermediaries between their target audience and the experts in these fields, administer the voice systems, organize the voice data for reuse. The fact that our voice platform allows such organizations to customize and control the operation of their own voice servers in a way similar to how they get to control their own web servers is important: it is the grassroots organizations who understand the local issues, who need to recruit and organize local experts who speak the local dialects, who need to constantly tweak the details of how their voice servers work to make their work more effective; centralized one-size-fits-all services just don't cut it in many situations. The language issue alone argues for local solutions: each of the top 22 languages of India is spoken by more than one million people and there are countless less popular languages and dialects.

The replication potential is also aided by the data sharing potential. For example, an NGO in a different state in India may wish to bring up their own voice server to serve a doctors' forum of their own. This new forum may benefit from the voice data that we have already accumulated in our voice forum, in terms of, for example, some of the most frequently asked questions and their answers. (In the vast Hindi belt, this hypothetical new forum should be able to share the existing voice data; elsewhere, translation by staff may be needed--the largely asynchronous nature of the voice forums
makes translation a natural part of the work flow.) Over time, the operator NGO of a new voice forum may start to add their own customizations, but initially, they might benefit from both the existing experience and data, making the learning curve less steep.

8. Prior Art

Does this work draw upon the intellectual property or substantive contributions of others who should be acknowledged and appropriately reference?

We have discussed the Lifelines system earlier. It allows farmers to leave questions on a voice mail system, which is monitored by Lifelines staff, who then source agricultural experts to provide answers, which are subsequently picked up by farmers as they dial in again later to retrieve the answers. Functionally, our doctors’ voice forum shares many commonalities with Lifelines: they provide much needed personalized help, harvest volunteer experts' input in a flexible manner, and have minimal demand on rural users' equipment and literacy needs in order for them to access the system.

As discussed earlier, the technology underlying our voice forums is significantly different from that of Lifelines. Lifelines' call handling system is based on a traditional model of running a PBX: a big centralized proprietary system housed in a telco's machine room, running proprietary software blessed and built by British Telecom. An analogy is a few expensive centralized web servers run by phone companies that are hardwired with pre-packaged one-size-fits-all "cgi-bin" scripts that cannot be changed directly by users: we wouldn't have had much of a "web" if web servers were controlled by phone companies like this.

In contrast, our forums are based on the open-source telephony framework called Asterisk, in terms of both hardware and software. The low cost and extreme ease of customizability makes it ideally suited for decentralized operation and flexible local adaptations, so instead of having to rely on a distant centralized and inflexible infrastructure, each grassroots organization can have its own highly customized voice server, running its own application, serving its own neighborhood of target audience.

Our project owes a great deal to Asterisk. It was initially developed by open-source enthusiasts in the late 90s to take programmable control from phone companies and place it in the hands of ordinary people so anyone could, in principle, write a program to, for example, turn his PC into an answer machine. Over the years, Asterisk has grown increasingly sophisticated and has become the de facto standard of an all-powerful open source telephony framework.

Our contribution, with respect to Asterisk, is two-fold. First, Asterisk, and its associated hardware, though very powerful, is notoriously difficult for novice programmers to set up. (One may think of it as the "assembly language" for phone hacking.) There have been many efforts of simplifying Asterisk but, unfortunately, these efforts almost uniformly end up sacrificing power so they could deliver something that's akin to a corporate voice mail system or a corporate PBX system, none of which is suitable for what we wanted to build. What we have done is building a database-driven layer on top that abstracts away much of the common chore required to construct the kind of voice forums that we have developed. Second, despite the great success that Asterisk has enjoyed, there have been relatively few substantial Asterisk applications built for developing world contexts. There are a few budding efforts but to the best of our knowledge, the kind of teachers' and doctors' forums that we have built is unique in
terms of substantial real-world deployments, extensive experiences gathered, and forum features developed over time based on these experiences. We have discussed some of these interesting forum features earlier: menu-less client operation driven by heuristics on stateful servers, management of auto-dialed schedules also driven by server heuristics, listener interest groups, synchronized voice server mirrors, "phone radio boxes," "remote-controlling" voice servers with phones, voice database features including indexing, searching, advanced queries, history-threading, key word tagging, usage history data mining, and much more.

The database layer that we have built is in part developed using Django, a popular framework originally intended for easy construction of database-driven web applications. The web interface that we have constructed using Django, along with its sophisticated database management features, allows users such as staff and some of the doctors to easily access and administer the voice database. We also connect Asterisk and the underlying voice database via the database API built with Django. We have observed that the kinds of voice forums that we have constructed share a great deal of commonality. Much of this commonality can be separated and encapsulated with Django database entities and their associated operations that we have defined. The entities include "persons," "organizations," "messages," "events," and on top of these, we construct additional abstractions such as "selections" and "call schedules." These common elements make the construction of similar sophisticated voice forums a much easier task: they allow us to focus on the aspects of a new voice forum that're truly unique.

We use the Red5 open-source flash streaming server to allow in-browser recording and streaming of voice.

Our voice forums share commonalities with radio call-in shows. They allow the exchanges of a few individuals to be heard by a larger audience. When the call-in shows put a few experts on the air to answer listener questions, both the call-in shows and our voice forums provide an opportunity for participants with specific questions to be connected with experts who can provide specific answers. They serve as "switchboards" for information exchange. Callers and listeners need only simple devices to participate.

Compared to our voice forums, however, the call-in shows have some important disadvantages. At the root of the problem is the fact that a radio show is a "mass media" device: even with the participation of audience members who call in, it's still the case that content produced by a few is beamed to a large audience--the hallmark of "mass media." In an on-air doctor format, most people who have questions can't get through to a call-in show; the show has only one or a few doctors so it's not harvesting a potentially much bigger pool of expertise and contributors; the show is on for only brief periods (far from 24/7); time-wise, it's not easy to connect a doctor and a questioner in real time. As an analogy, think of the difference between YouTube and plain old "tube."

Having said that, we believe there are important synergies between our voice forums and radio, which we plan to explore. We have had discussions with All-India Radio so that we could recruit volunteer doctors and other participants of the voice forums on air. Voice forum exchanges involving common issues could be put on air to reach a larger audience. There's also the possibility of connecting voice forums like ours with community radio stations that cater to smaller and more focused audiences.

Our doctors' forum also shares common elements with some existing for-profit doctors' call centers. In our experience, when potential volunteer doctors are under the mistaken impression that we operate a call center, they have been almost uniformly reluctant to join. It's a format that they perceive to be too inflexible and require too big a commitment from their already busy schedules. They typically become much more receptive when they realize how we operate differently from a regular call center. In addition to the flexibility that we offer our volunteer doctors, there are some other
differences. We see the doctors’ forum more as an educational tool than a diagnostic one. As such, we provide features such as signing up villagers who opt in to receive periodic calls from the forum and listener "interest groups."