Which has greater liquidity: money, education or drinking water?

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Abstract
Often, international development efforts focus upon meeting basic needs (e.g. access to water and sanitation) such that a community can invest more time in economic pursuits. In this paper we trace the evolution of our approach to meeting basic needs over the course of eight years and three case studies. We describe our shift from a traditional approach to providing water access according to the Engineers Without Borders model, to an alternative approach where we consider income and education as primary causes of improvements in health rather than secondary effects of improved clean water access. Ultimately we conclude that the most effective way to promote sustainable development is by increasing income via access to employment using crowdsourcing, which will lead to improved village health and reduced diarrhea burden.

Keywords
crowdsourcing; sustainable development; alternative strategy

INTRODUCTION

Some in this research community are working on the problem of providing water treatment technology to communities in developing countries as a way to alleviate extreme poverty. The idea is that extreme poverty is characterized by deficits in basic needs, and directly eliminating those deficits (e.g. by the construction of a water treatment and distribution system) will lead to "development," and the elimination or reduction of extreme poverty. Here "development" is typically assumed to mean "economic development," and the narrative is that when basic needs are met, poor people are able to devote more time to economic activities and then, finally, begin on the path of economic growth. Specifically in the case of water infrastructure interventions, this story typically goes, "We made clean water more easily accessible, and so the women and girls in the village can spend less time collecting water and more time in productive pursuits or going to school," or "With clean water, people get sick less often (i.e. reduced diarrheal health burden), and then they can be more productive." The assumed direction of causality, or the propagation of consequences, is from "meeting basic needs" to "increased productivity" to "economic development". The authors at one time subscribed to this basic view of environmental engineering in support of poverty alleviation.

In their book *Poor Economics* (Banerjee and Duflo 2012), Banerjee and Duflo make a strong case for the necessity of measuring the effectiveness of interventions on a case-by-case basis. Meanwhile in *The White Man's Burden* (Easterly 2006), Easterly shows that traditional aid interventions create damaging individual incentives (e.g. dependency on handouts) and argues for a re-examination of development work through the lens of incentivized behaviour.

In light of such work from the development economics literature, it is worthwhile to revisit the narrative of development that underlies environmental engineering work on poverty alleviation. In this paper we relate the evolution of our views on the usefulness of water projects for international development work by considering three case studies from our work over the past 8 years. We consider 1) an Engineers Without Borders (EWB) water project, 2) a research study to quantify the determinants of the impact of household slow-sand filters on diarrheal health burden, and 3) a pilot project to use crowdsourcing to provide employment to rural villagers. For each project we provide a brief background and description, and then discuss the lessons learned and how the project has affected our views on how we should go about our development-related work.

ENGINEERS WITHOUT BORDERS WATER DISTRIBUTION PROJECT

In 2007 our EWB chapter began work on a water distribution system in Kamuga, Kenya, a community of approximately 500 people in a region where 64% of the inhabitants live below the $2 per day poverty line (Kenya National Bureau of Statistics 2005). A team of undergraduate engineering students performed the community assessment (2007), design, implementation (2009), and post-implementation evaluation (2010) of 1) a solar-powered groundwater pump, 2) two aboveground concrete storage tanks, and 3) five kilometres of distribution system for domestic use, animal husbandry, and kitchen gardens. Total project cost was approximately $50,000. From our experience with EWB-USA, this project was typical of water infrastructure projects undertaken by EWB chapters.

While we conducted pre- and post-implementation evaluations in the community to measure the impact of the project, this type of data, even when properly collected, does not provide credible evidence about the effects of the intervention (Banerjee and Duflo 2012). Credible evidence would require a valid counterfactual (or "control") community, with data collected in both the intervention community and the counterfactual community before and after implementation. However, due to the turnover of undergraduate students in EWB chapters, maintaining a long-term commitment and the expertise to do effective evaluation is prohibitively challenging. With apologies to the donors who contributed to this particular project, our fundraising claims about the "long-term sustainable development" initiated by that intervention remain unsubstantiated. Again, we find this lack of rigorous evaluation to be typical of not only EWB projects, but many of the projects undertaken by the environmental engineering research community (quite understandably, because rigorous evaluation is indeed quite challenging). To their credit, in 2013 EWB released new guidelines to improve project evaluation (Martindale 2013), but they still do not address the fundamental problem with credibility described above. Some evaluation is definitely better than none, but we must avoid claiming that we know more than we actually do about the impacts of our work.

Secondly, through the course of that project and our continued involvement with that community, it came to our attention that the community leaders were soliciting aid from three different international organizations and one domestic organization simultaneously for water and building construction projects, without disclosing these arrangements to any of the four organizations. Imagine the surprise upon crossing paths with a volunteer from another organization during a visit to the community. While we found these revelations to be somewhat concerning, such conduct is unsurprising, as it is an economically rational response to the incentives created by this system of aid. If significant investments in capital infrastructure are on offer from various organizations, then "playing the field" is an effective strategy for maximizing the expected benefit to one's community.

Occasionally (probably not often enough) development practitioners express some concern related to their awareness of the cultural changes brought about by their interventions (e.g. the elimination of the communal well as social space). We certainly share this concern and do not have a resolution to offer to ameliorate it; we think it does not go far enough. We discovered (after construction) that some of the wealthier community members had been (prior to construction) paying some of the poorer community members to collect water for them. With the introduction of easily accessible water for all, we had unintentionally eliminated some sources of employment and possibly even contributed to increasing inequality within the community. These are challenging issues that should be taken into consideration during the design of such projects.

Iatrogenesis

Here we would like to promote the concept of iatrogenesis in the discourse on development interventions. Iatrogenic is defined by Merriam-Webster dictionary as "induced inadvertently by a

physician or surgeon or by medical treatment or diagnostic procedures". In *Antifragile* (Taleb 2012) Taleb notes that it has only been within approximately the past century that physicians began to do more good than harm for their patients, as a result of such practices as bloodletting and the absence of good hand-washing hygiene (despite the axiom of *primum non nocere,* or "first, do no harm"). Taleb goes on to broaden the concept of iatrogenesis to a variety of domains including finance and education, and warning of "naïve interventionism," or interventions without consideration for possible iatrogenics.

The concern about changing cultural systems, the elimination of the water-hauling jobs in Kamuga, and Easterly's concerns about the incentives created by aid all represent cases of iatrogenesis in the realm of development work. We encourage engineers who participate in development work to give serious consideration to the possibility of inadvertent harm, and adjust their activities accordingly.

Water access is not sustainable development

There are many competing definitions of sustainable development, but common among them are the concepts of 1) continuation for a long time rather than short time and 2) state change, from the present state to a future state. Providing water access is often held up as an example of "sustainable development" – we have spoken of this ourselves – but does it meet these two requirements? Infrastructure costs money to maintain over time; if a community cannot pay for maintenance over the long term, then the project is clearly not sustainable in an economic sense. If they cannot already pay for such costs, then economic state change is required. This ultimately requires livelihoods; and if they are not already present or sufficient, providing a water infrastructure project will not necessarily change that. There is at best an indirect and uncertain link from water access projects to long-lasting state change; this should be obvious from the many failed projects of the past that now sit broken and unmaintained.

We caution that usage of the term "sustainable development" with regard to water projects may function as a "semantic stop sign" (Yudkowsky 2007) – that is, a label which, once applied, prevents the asking of additional challenging questions. Of course "sustainable development" is a good thing; but how exactly will an expensive water infrastructure project that a community could not afford on its own be "sustained", and exactly what "development" will result from easier access to water, and on what evidence do we base our answers?

STRUCTURAL EQUATION MODELING OF THE DETERMINANTS OF THE IMPACT OF WATER FILTERS ON HEALTH

In 2009, Divelbiss began work to use structural equation modelling (SEM) to investigate the complex set of factors mediating the impact of water filter interventions on diarrheal health burden (DHB). SEM has two important strengths for this type of analysis: 1) the use of latent (unobserved) variables like socioeconomic status (SES), which are estimated based on multiple observed variables such as ownership of a vehicle, and 2) the ability to represent both direct and indirect relationships between variables. Household surveys were conducted in rural Guatemala (n=286) in homes where the Centre for Affordable Water and Sanitation Technology (CAWST) filter was in use.

The results of this work (see Divelbiss, Boccelli, Succop, & Oerther, 2013 for details) show that while a properly operating and maintained CAWST filter is associated with a decrease in DHB, increased household education is associated with an even larger decrease in DHB. Further, the full SEM model, which accounts for household education, socioeconomic status, hygiene practices, quality of water source, and extent of additional water treatment in the home, explained only 7% of the variance in DHB. Divelbiss notes:

> "*The community is a complex system of interactions which directly and indirectly influence the health of its residents. Policy makers and development practitioners must recognize that single target interventions (e.g., improving water quality) have a limited influence on the entire system.*"

In addition, Voth-Gaeddert has extended this approach, using data from the US Agency for International Development (USAID) Demographic and Health Surveys (DHS) Program and a combination of SEM and the Mahalanobis-Taguchi System to show that increases in household education level are correlated with reduced overall household health burden (Voth-Gaeddert et al. 2014).

Considering these results, and the results of the seminal Whitehall studies (Marmot et al. 1978; Marmot et al. 1991) which showed that socioeconomic status has a strong impact on health, we must conclude that we can achieve gains in household health not only by directly providing interventions like water filters, but also by 1) improving household education and 2) improving socioeconomic status.

CROWDSOURCING-BASED EMPLOYMENT AS AN ALTERNATIVE APPROACH

With the above lessons in mind, we pivoted to a drastically different approach to engineering development practice, focusing on employment to increase SES instead of directly providing technological solutions. In 2011, we began a pilot project to test the feasibility and investigate the impact of providing employment through a crowdsourcing work platform. Crowdsourcing is a novel labour organization paradigm which "represents the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call" (Howe 2006). Crowdsourcing is a "high growth, early stage industry" (Massolution 2012) that has the potential to radically transform the way work is done in the future (for a thorough review and a vision of the future of crowd work, see Kittur et al., 2013).

Seven villagers from Kamuga (site of the EWB project) were recruited to perform crowdsourcing tasks with a rate of pay of approximately six dollars per day. This compared favourably with the prevalent rate of pay of approximately one dollar and fifty cents over the same period. The workers were provided with four laptop computers, recharged using a portable solar array, and connected to the internet via 3G wireless modems. Each worker reviewed images collected from peer reviewed, archival biochemistry journals as part of a data mining project, paid for by the bioinformatics researchers who received the data (Schriner, Oerther, and Uber 2011). Over a period of approximately two months, the workers earned a total of two thousand dollars with each worker receiving a fraction of the total in proportion to the number of images reviewed.

Approximately six months after payment, five of the seven workers were interviewed and asked to recall how the funds had been spent. Figure 1 provides the responses of each worker normalized to the total amount of income received. Without prompting, each worker reported that more than 50% of his or her income was spent on education. These results support the hypothesis that access to income can result in improved education for villagers. The remainder of the income was spent on basic needs such as food and clothing, productive investments in small businesses or farming, and goods such as kitchen pots or radios. It is important to note that under this arrangement of employment for income, the liquidity of money allows individuals to meet their most pressing basic needs and make investments in their futures in the ways they find most compelling.

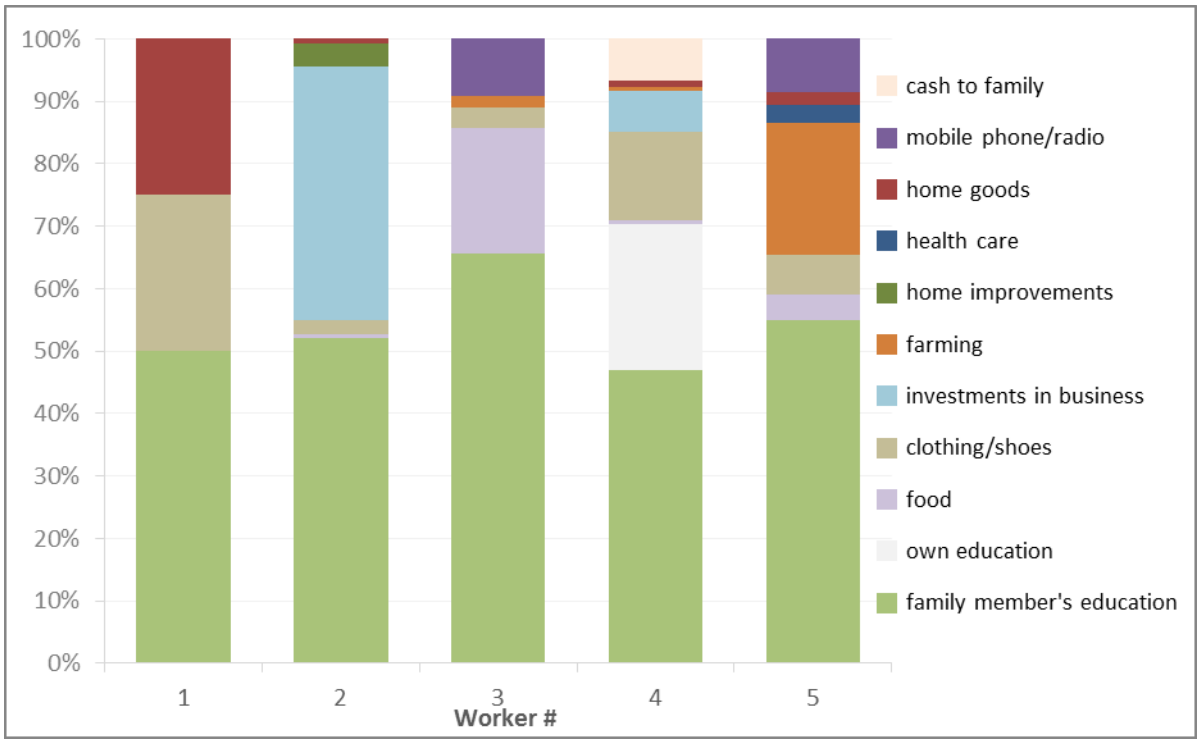

Figure 1 Distribution of spending for 5 crowdsourcing workers in a Kenyan village.

We currently believe that crowdsourcing employment is the most promising approach for reducing poverty quickly and at scale. This approach addresses the root cause of poverty (lack of money); it creates value for both workers and requesters of work (as opposed to aid, which relies on donations and merely transfers value); and it utilizes virtuous market incentives that align with social good. Access to the necessary computing infrastructure poses a challenge, but cybercafés, microfinance, and smartphones provide realistic options to lower the barrier to entry. The crowd work industry is large and growing; disbursements to workers totalled $2 billion in the first decade of the industry's existence (Frei 2009). The biggest challenge is ensuring that crowdsourcing work is made widely available so that workers in developing countries have the opportunity to participate.

CONCLUSIONS

Development work is a significant challenge that has beguiled practitioners for decades, so we must think critically about our approach and learn from experience, lest we fall victim to the mistakes that have plagued the past. It is understandable that environmental engineers, with their water-related expertise, would gravitate toward water technology solutions to the poverty problem – "when holding a hammer, everything looks like a nail". However, this is not an acceptable justification to keep doing the same things without careful evaluation of the results. Over the course of several decades of evidence, it is not clear that the old approach is effective, and so new methods are required.

Through the experiences described above, we have come to believe that the most effective way for engineers to effect sustainable development is to provide employment opportunities (specifically via crowdsourcing). We would go so far as to say that, knowing what we know now, if we had the opportunity to go back 8 years, we would work on crowdsourcing employment, and not EWB projects. The incentives and the liquidity provided by income earned through employment represent a paradigm-shifting improvement over the old way of providing development aid.

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