Water treatment and supply: intermediate education in Sub-Saharan Africa
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ABSTRACT

In 1973 the economist E.F Schumacher wrote ‘Small is Beautiful’. In this he created the vision of a concept known as ‘intermediate technology’. Directly from this grew the popular ‘appropriate technology’ movement. An appropriate technology, in the ideal sense, is designed with special consideration of the environmental, ethical, cultural, social, political, and economical aspects of the community it is intended for. The term ‘appropriate technology’ is continually used when referring to water supply and treatment technologies in international development. The widespread provision of hand-pumps in Africa by Non-Governmental Organisations (NGOs) fully characterises the approach and remains the most prominent display of technologies, transferred on a charitable basis, between the developed and developing countries. However, after years of NGOs working with hand-pumps in Africa the first signs are showing that there are widespread problems with the current approach. In many cases the nature of ‘appropriateness’ is determined from the perspective of an external technical expert and not by the communities themselves. The lack of appropriateness is leading to severely unsustainable projects. This paper explores the linkage that has not been clearly mapped in technology transfer, i.e., the use of scientific and technical education. The focus of the transfer is on developing the knowledge and skills necessary to evaluate ‘appropriateness’ from the perspective of the end user. It explores the concept of ‘Intermediate Education’ – a method of using experimental learning to address a systemic weakness in safe water provision in development.

Key words | appropriate, education, intermediate, international development, technology

INTRODUCTION

A recent global estimate of water supply in the developing world suggests that 884 million people still require access to safe drinking water (WHO & UNICEF 2008). Optimistically this indicates that 1.6 billion people have now been granted access to safe drinking water since the 1990s. Some of these solutions have been large, centralised and capital intensive projects like piped water systems and dams. However in Sub-Saharan Africa, where generally speaking these large scale solutions for a myriad of reasons are unavailable, the situation remains unresolved. Many of the inhabitants of Sub-Saharan Africa are now classed globally as the ‘bottom billion’ (Collier 2007). Due to the rural nature of much of the poverty, safe water supply is generally dependant on small scale, labour-intensive and ‘low’ technologies. Recently, due to large international pushes, improvements have been reported in water supply provision. However the rate of progress, as reported by certain UN agencies, makes the assumption that those that have been provided with an improved source have continued to use them in a sustainable fashion (WHO & UNICEF 2008). This is contrary to independent studies which suggest that this is not the case. In a selected range of countries in Sub-Saharan Africa it is estimated that between 30–60% of pumps fail and that at any given
time only two out of three pumps are working (Hazelton 2000; DWD 2002; Sutton 2005; Harvey 2007). One of the few relatively recent surveys, carried out in Tanzania and looking historically at water supply systems, suggests that over a 25 year period there is a 90% failure rate of water supply projects (Haysom 2006). As the problems facing rural water supply are wide-ranging there is no single mitigation or remedial action available.

**Engineering in international development**

Much of the engineering carried out in developing countries is identical to that of a developed country in that it is primarily capital intensive. However, to suit the needs of the poorest, the engineering carried out by Non-Governmental Organisations (NGOs) has begun to differ from traditional engineering approaches, and is defined as development engineering. Development engineering is more focused on village level and labour-intensive approaches. It has been argued that development engineering requires continual local participation in order to be successful (Skinner 2003). The technologies adopted are often considered ‘low’ technologies, i.e., ones that do not require specific specialisations to manufacture and use. These technologies include examples such as hand-pump wells, water filters, smokeless stoves, ventilated improved pit latrines and rainwater harvesting systems. The Millennium Development Goals state that, by 2015 the global community will reduce, by half, the proportion of people without sustainable access to safe drinking water (UN 2000). The primary response by the developed countries to this goal has been to supply hand-pumps to resolve water supply issues. However, as discussed before, sustainability is a key issue in these development projects. It has been suggested that at a fundamental level sustainability depends on the relationship between the technology, the engineer and the communities themselves (Carter et al. 1999). The widespread failure in sustainability points to a systemic problem regarding how the technologies are transferred, and the capacities of the communities to receive these ideas. This paper is concerned with an issue that Schumacher expressed as the ‘missing link in the whole enterprise’ – the use of education (Schumacher 1973).

**PREPARING SOCIO-TECHNICAL SYSTEMS**

This paper explores three arguments which promote the need for developing the socio-technical systems in international development: (i) technology acceptance in development, (ii) indigenous and scientific knowledge, and (iii) participation in development.

**Technology acceptance in development**

Successful technology integration is most clearly observed in the widespread adoption and use of mobile phone technologies throughout Sub-Saharan Africa (Smith 2009). It is possible to travel throughout Africa, to some of the poorest and most remote areas within its interior, and find villages with no water supply or functioning sanitation systems, but an abundance of mobile phones. It is even possible to find local phone repairmen, as well as all the associated luxury items and paraphernalia which accompany these phones. These markets are thriving with mobile related wares, a private sector response that has developed without, or possibly despite, NGO involvement (Smith 2009). This can be juxtaposed against the private sector involvement in water supply technologies. Much of the failures of water supply projects are attributed to the lack of, or weak, private sector involvement. So why are mobile phone technologies succeeding where water supply technologies are so clearly failing? The response essentially draws on one of the most fundamental market philosophies – supply is entirely dependent on demand. Mobile phone technologies ultimately address a perceived need. This need creates the demand, and that demand creates a market thus ensuring private sector involvement. It would be condescending to suggest that those in developing countries do not demonstrate a clear understanding of the importance of drinking water. Neither do these people willingly accept a water supply that may look as though it can cause harm. However, there is widespread acceptance of sources that would not suffice, even on a temporary basis, for those in a developed country. This poses an important question: can those in poverty simply be told that a source of water is unacceptable, and will this suffice for them to change their interpretation of their needs?
Developed countries can often overlook the social factors that allowed their health systems to develop. For instance, the history of the United Kingdom has many examples of scientific breakthroughs being rejected when its own society was not prepared to hear, or to understand, what was being suggested. There is no better example than that of the 1854 cholera epidemic in the water supply in Soho, London (Johnson 2006). Dr John Snow famously used this outbreak to contradict the miasma theory (that cholera was caused by ‘bad air’). He traced the Soho outbreak to a single public hand-pump well. This well had been dug less than three feet from a cess-pit. After using statistics to prove the connection to the illnesses, the pump handle was removed. As the pathogenic theory of medicine (or germ theory) had not yet been discovered Dr Snow had no way of articulating how the mechanisms of the disease worked. This may appear to be a triumph in effectively sensitising local residents, without imparting the full scientific facts, when dealing with water supply issues. The final part of the story suggests otherwise. After the cholera outbreak had subsided the government, still uncomfortable with the idea of a faecal-oral transmission route, reinstall the handle of the hand-pump. It was not until the widespread acceptance of germ theory in the late 19th century that the transmission routes of cholera were understood. The Soho cholera outbreak offers parity to the current actions in the developing world. Simply sensitising communities might work in the immediate context of an emergency, but is severely flawed as a sustainable intervention. In international development, community water systems are allowed to fall into decay. It has also been noted that when a system stops working the users return to their previous sources of water. This indicates that there is very little development of the scientific understanding of their problems. Therefore to suggest that a community aspires to ‘safe’ drinking water precludes that there is some recognition of a scientific understanding of what this entails. Without ensuring clarity on some of the fundamental aspects of science there exists no basis upon which to build a suitable appreciation of either the problems or solutions that are available.

Indigenous and scientific knowledge

Introducing scientific understanding to effectively deal with global water issues is crucial for sustainability. Scientific knowledge is not, however, a silver bullet. Overemphasising the importance of science can result in it being mislabelled as ‘truth’. Science offers only one of the many ways of understanding the natural world. Therefore scientific knowledge requires its own scrutiny in relation to sustainable development.

Scientific knowledge is a body of reliable knowledge that can be logically and rationally explained; it can be repeatedly tested and verified through experimentation, and is used to make empirical sense of the natural world (Aristotle, 4th century BCE 1989). It is acquired through long periods of inquiry and investigation, and in the ideal sense, a combination of complete human learning which is collated, compiled, analysed and sourced from a wide range of social and cultural backgrounds as well as historical periods. This is comparable to indigenous (or traditional) knowledge, which generally refers to the long-standing traditions and practices of certain regional, indigenous, or local communities. In many cases, traditional knowledge has been orally passed down for generations from person to person. Many forms of indigenous knowledge are expressed through stories, legends, folklore, rituals, songs, and laws. This knowledge generally evolves to better understand local conditions and issues. It is regarded as the basis for local-level decision making in issues such as agriculture, education, natural resource management and a host of other activities (Warren 1993). There are similarities with scientific and indigenous knowledge; both seek a way of understanding the natural world, both use a method of experimentation to generate proof and both are used to govern knowledge, attitudes and practices. Developed societies have their own forms of indigenous knowledge; those with little scientific merit become ‘urban legends’ or ‘old wives tales’, those with merit become incorporated into normal living practices. There are many examples of this type of knowledge evident in the developed world’s culture. They also exhibit the ability to discredit harmful myths by using their scientific understanding of the natural world to do so. However, even in the developed world, the success of this ‘debunking’ process generally depends on the scientific abilities of those involved.

Engineering can, at least partially, be described as an applied science: the application of scientific knowledge transferred into a physical environment. As such, engineering inherits both the strengths and weaknesses of scientific
knowledge. It uses the current understandings of scientific facts as a firm basis upon which to create internationally recognised standards. These are then used to govern engineering practice. Rejection of this core principle of engineering would be counterproductive. It is argued that knowledge of scientific principles, the ‘laws of nature’, of materials and of methods are in a sense, absolute (McRobie 1981).

This paper suggest, that for all the opportunities that science offers, it is this ‘absoluteness’ that creates the systemic problems when dealing directly with communities with little or no scientific background. The most disruptive aspect of scientific knowledge is its sheer dominance over ‘traditional’ or ‘indigenous’ knowledge. ‘Modern scientific knowledge is centralised and associated with the machinery of the state; those who are its bearers believe in its superiority. Indigenous technical knowledge, in contrast, is scattered and associated with low-prestige rural life; even those who are its bearers may believe it to be inferior’ (Chamber 1980). It could be argued that engineering in international development, exemplifying the core philosophy of this scientific dominance, follows exactly in the same vein. The justification for this domination is that ‘indigenous’ knowledge has no scientific basis and therefore should be omitted from engineering practice. In doing so, the rejection of indigenous knowledge omits the single most defining aspect of appropriateness, and hence the sustainability of a technology: the context upon which the technology relies – the very part that makes it ‘appropriate’.

**Participation in development**

The lack of context in technological interventions in developing countries is observed in more than one area of engineering practice. Because water supply projects, particularly hand-pump wells, produce such positive short term results with regards to the reduction of water related infections, the social and cultural implications of a technical solution can often go unnoticed and unchecked. The cultural practices of a community have to change, sometimes dramatically, in order to openly receive a water supply technology. In exploring the concept of intermediate technology E.F. Schumacher called for ‘...a gentle approach, a non-violent spirit, and small is beautiful’ (Schumacher 1973). One of the key attributes of ‘gentleness’ is a willingness to accept terms upon which a project could be rejected, or perhaps more crucially, redesigned in line with the environmental, ethical, cultural, social, political, and economic needs of the communities. The redesign of a project solution is reliant on the technical capacity of a community. Some practical alterations are not suggested because of the ‘locked in’ aspect of technology transfer. The community does not have the ability to suggest reasonable alterations to a technology because of their limited technical and scientific grasp of what they are being provided with.

The increase in ‘participation’ within development projects; over a number of development sectors has been shown to increase both the ownership and long term sustainability of a project. Ideally speaking, community participation is a consultative empowerment process which is designed to establish communities as effective decision-making entities (Harvey & Reed 2007). For the community to be involved in a water supply project there must be information sharing, consultation, decision-making, and initiating action (Guijit & Shah 1998). Due to the lack of technical teachings generally found within local communities, participation remains severely limited. This vacuum allows the engineer or ‘technical expert’ to dominate (Botes & van Rensburg 2000) and this unintentionally leads to the use of manipulation where ‘...participation is undertaken in a manner contrived by those who hold power to convince the public that a predefined project or program is best’ (Duraiappah et al. 2005). This reduces the communities’ ability to problem-solve technical issues for themselves and in doing so creates a culture of dependency. Water supply projects must be capable of being maintained at the village level and this requires the users to be completely comfortable with all parts of the technology. Participation has to extend to more than just permission for land use, identification of site locations and labour provision. If a community, without basic scientific and technical knowledge, is unable to make a reasonable input into the design aspects of a water supply and treatment project, then this should be regarded as one of the root causes of lack of ownership and sustainability.
DISCUSSION

Science and technology education in the developing world

The dialogue, between those with indigenous and those with scientific knowledge, needs to be created. This link is crucial for three reasons: first, to develop a market for water supply and treatment projects; second, to be linked with indigenous knowledge to create a ‘context’ for the technologies; and lastly, to provide a dialogue which allows communities to engage with the engineers, thereby presenting a gentler way of technologies being adapted and accepted into community life. Therefore the importance of scientific teaching in a development context cannot be understated. The most obvious place to look for these teachings is within the education systems of the developing countries themselves. In the developed world it is these institutions that are initially responsible for sharing scientific knowledge. A basic overview of science and technology education in Sub-Saharan Africa is not altogether positive:

- Similar to the schooling systems of the developed world, science classes such as physics, biology and chemistry are most commonly found in a secondary school teaching curricula. However Sub-Saharan Africa suffers from a massive underinvestment in secondary schools. Over 70 million of the region’s secondary school-age children are not enrolled in secondary schools (Lewin 2007).
- As discussed before, many of the poorest people in development are typically found in rural areas. Due to the lack of financial support secondary schools are generally found in urban and peri-urban environments in developing countries. In lower secondary education, for example, the average gross enrolment ratio is 66.5% in urban areas, but only 22.2% in rural areas. The pattern of coverage does vary over countries (Mingat & Ndém 2008). Overall people in rural areas are less likely to receive a science or technical lesson.
- Within the secondary schools that are available, whether rural or located not, there is a common lack of materials and teaching resources. Crucially, this limitation ensures that science and technical education is taught didactically. This severely limits the effectiveness of the teachings and could potentially alienate students from the subject matter. This is taught counter to best pedagogical practices (Freire 1970).
- Finally, the education of science and technology is fashioned directly on the curricula used by the developed nations. The academic irrelevances and alien concepts make them less suited to their role within a developing country (Harrison 1979). This in turn can enhance human flight capital – the brain drain.

The ideal situation would be to have secondary education widely available, with science classes taught in the most effective manner, with all available resources to ensure that there is the capacity to do so, while also providing a curriculum that is both useful and relevant for a Sub-Saharan African. Due to financial requirements, this remains outside the capacity of development agencies to provide. The provision of secondary schools should remain a long term goal of development; however, simply ignoring the importance of scientific and technical education is severely affecting both the short, medium and long term effectiveness of water supply and treatment projects.

NGOs currently engage in a form of community education. They do this by using sensitisation: limited teaching practices that are dependent on the community accepting what the NGO teaches, without the opportunity of exploring the nature of the lessons in more detail. This practice is similar to Dr Snow’s efforts in Soho – though he was not at the time withholding information, but was unaware of the full situation himself. The ultimate ambition of sensitisation is not to encourage scientific growth but to mobilise a community to effectively deal with their health issues. For example in sanitation awareness ‘health and hygiene promotion’ has already provided a very important role in mobilising communities to understand their health situation. Kamal Kar’s Community Led Total Sanitation (CLTS) has already been pivotal in demonstrating the seismic shift that happens when a community fully grasps the immediacy of their situation (Kar 2003). The triggering method adopted by Kar does not fully include a scientific understanding of the problems, instead uses disgust and embarrassment to alter community practices. This use of sensitisation cannot be faulted.
in itself, as it has very successfully contributed to a widespread adoption of ‘defecation free zones’ and safer sanitary practices. However, Kar admits that one of the most limiting factors is getting communities to aspire to climb a ‘sanitation ladder’ (Kar 2003). This again relates to the importance of scientific and technical education.

**Intermediate education**

The economist Schumacher fully understood the importance of intellectual support. He claimed that the gift of useful knowledge was the best aid that could be given (Schumacher 1973). What this study suggests is providing a form of intermediate education as the basis for this educational support. This would be intermediate between scientific and indigenous knowledge, between full scale education systems and sensitisation and between the cultures of the developed and the developing worlds.

Richard Feynman, the Noble laureate in Physics, argued that the test of all knowledge was to experiment – the sole judge of scientific proof. Experiments produce, he maintained, the laws that give us hints about our world. Allied with our imaginations they develop to become the ‘great generalisation’ allowing us to see the great patterns beneath the laws, only to experiment again to see if the correct guesses were made (Feynman 1964). Experimentation is, in short, a crucial aspect of scientific learning. The term ‘intermediate education’ refers to a form of capacity building of the host community which primarily builds their scientific and technical understanding by exploring, through experimentation, issues which affect them, and the solutions that are available. The defining attributes of the Intermediate Education concept are:

- **Promotion of scientific and technical growth**: The primary function of the intermediate education concept is to ensure that there is an increase in scientific and technical growth in the host communities. This should not be confused with capacity building, which focuses on teaching related to the construction, operation or maintenance of a water supply and treatment project. Capacity building is a vital aspect of water projects, but is specifically geared towards community participation external to the technology itself, not in the community understanding of the sciences used to create, develop and design the technology. Similarly, intermediate education is not intended as an exercise in health and hygiene promotion; instead it is intended to show the scientific nature of both the health problems, as well as the solutions. Though both capacity building and health promotion would be complimented by the intermediate education concept, it remains independent and has its own unique focus and contribution to a water project.
- **Experimental learning**: Intermediate Education uses a form of teaching which depends almost entirely on experimental learning. This hands-on experiment-based learning allows for full participatory interaction by students. It can also be conceived as providing empowerment, as certain experiments can unlock the problem solving potential of those being educated.
- **Technology catalyst**: Though this paper challenges the usage of the term ‘appropriate’ it is not intended to diminish the importance or necessity of a technical intervention. The opportunity to provide intermediate education would not exist without a technological intervention. Intermediate education is intended to fulfil a role linked directly to the ‘technology transfer’ of a water treatment and supply solution. For this reason it uses the technology which is presented to the community, such as a BioSand filter, or Rainwater Harvesting Systems, as a catalyst for engaging with the host community. The experiments are directly associated with this catalyst and not intended to be independent.
- **Material Resources**: The experiments themselves must be capable of being sourced and created locally using only sustainable and renewable resources. Recycled materials are ideally suited for this purpose. The experiments however cannot misrepresent the scientific integrity of the concept being explained. School equipment which requires high capital investment, such as Bunsen burners and microscopes, should be avoided where possible. Experiments that depend on metaphoric interpretations, such as using humans to ‘represent’ micro-particles, should be also be avoided unless deemed vitally necessary.
- **Open Access**: The experiments have to be developed in a way that ensures that they are inclusive to all members within the community. Though the experiments would
most comfortably compliment a school curriculum, it should also be suitable for those outside the education system through peer-to-peer groups and existing community social networks. The material should also be developed in such a way that purposely ensures the participation of women and children. Providing technical support for both these groups is specifically mentioned in the charter of human rights (Byars et al. 2009).

This type of education could comfortably fit within current water resource projects. It would involve only a fraction of the total project costs. Health and hygiene promotion has already indicated that educational components can be considered important contributors to engineering projects in development. The intermediate education concept would also give ample opportunities for developing world technicians to work with local education authorities. This would allow more end-user feedback for the technologies, which has been conspicuously lacking in development engineering programming. It would also allow the capacities and skills of the technicians to be further developed that are appropriate for the local needs of the communities. Like the CLTS concept, skilled facilitation is key to making this approach work.

Though the intermediate education concept may develop demand and thus create a market system, or assist in making technologies more appropriate, or simply support an education system, the results will not be dramatic in the short term.

CONCLUSION

The intermediate education concept is purposely aimed at achieving long term growth in the developing world. Engineering in development should not only be about applying a technical solution to a systemic problem; instead it should also be about developing the capacity of a socio-technical system to adapt its own version of ‘appropriate’. The concept of intermediate education seeks not to dominate but to bridge the gaps between disparate worlds. It seeks to more fully involve communities in the designs that affect their lives. It should allow a community to participate more fully in a project, consistent with their cultural beliefs, without sacrificing the scientific integrity and the health benefits of safe drinking water. It should also offer a form of engineering empowerment, allowing those facing scientific problems to not only understand the nature of their problems, but to know where to look for solutions, be that the private sector, their local civil society groups or perhaps themselves. And finally the intermediate education should work directly with those who need the tools to effectively form their own future – the children of the developing world. Therefore this concept would directly fulfil Schumacher’s true spirit of appropriateness – a gentle approach, a non-violent spirit, and small is beautiful.

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