ICTs for Global Development and Sustainability:

Practice and Applications

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Chapter 5
Digital Doorways

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ABSTRACT

The Digital Doorway is a joint initiative between the Meraka Institute of the Council for Scientific and Industrial Research (CSIR) and South Africa's Department of Science and Technology (DST), with a vision of making a fundamental difference to computer literacy and associated skills in the South African population. Underpinning the project is the idea of people's inherent cognitive ability to teach themselves computer skills with minimal external intervention. For this to happen, computers must be easily accessible to potential learners in an environment conducive to experimentation. Given the low percentage of communities in disadvantaged areas in South Africa with access to computer infrastructure, Digital Doorways are installed in communities where the need is greatest. The systems are extremely robust and employ open source content. The project team has moved from an action research to a design-based research paradigm, simultaneously deploying and improving the systems over the past six years. The novel method of instruction (unassisted learning) and the challenging operating environment call for both innovation and careful engineering of all aspects of the system. User interaction at the sites has been carefully observed. Numerous challenges, complexities and controversies, both social and technological, have surfaced and continue to surface as the project progresses. Valuable learning has been acquired around community engagement, ownership and site acquisition and numerous 'soft' issues that ultimately determine a project's success or failure. Both qualitative and quantitative research have been conducted. Feedback from users has been mostly positive and there is a demand both from government and private sector companies for many more Digital Doorways to be deployed throughout South Africa

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and worldwide. Sustainability, community ownership and maintenance remain the greatest challenges to the long-term success of the project. Despite the challenges, unassisted learning can be effectively used to provide basic computer literacy training in rural and impoverished communities in South Africa.

INTRODUCTION

On the outskirts of Kei Mouth in the Eastern Cape province of South Africa, lies the impoverished township of Cwili. The residents of this area were the first recipients of a public computer terminal (see Figure 2) designed by the Council for Scientific and Industrial Research (CSIR) to provide an alternative means of ICT literacy delivery, where the focus was specifically on learning without formal teacher intervention. The novel ICT education project was named the 'Digital Doorway' (DD) and from its humble beginnings in 2002, grew to a large multi-provincial drive to increase computer literacy in South Africa.

This chapter will provide an overview of the DD project, highlighting some of the technical aspects of the design, the research philosophy, various social issues encountered, and some of the lessons learned during its six years of implementation. The mix of theory, technical challenges and social aspects reflects the complexities that are encountered in projects of this nature.

BACKGROUND AND OBJECTIVES

There is a great need for increased access to computer infrastructure in South Africa and Africa. Table 1 tabulates the extent of schools with computers for five African countries.

In 2000, Dr Sugata Mitra of NIIT, India began his innovative 'Hole In The Wall' experiment by placing a computer into a recess cut in a wall. Via a video camera in a tree, he observed how members of the community interacted with this high tech device, even though they had never before used a computer (Mitra, 2000). After some months of observation Dr Mitra concluded that unassisted learning through trial and error is indeed an effective mechanism for supporting the acquisition of basic ICT literacy skills. NIIT proceeded to deploy similar devices around India (see Figure 2).

The CSIR in South Africa exists to promote basic research and to find mechanisms for that research to be turned into beneficial implementations. One of the CSIR's goals is to find ways of making a tangible improvement to the lives

Figure 1. Users, both young and old, of the first Digital Doorway (a single-terminal), in Cwili, Eastern Cape, South Africa. This DD was the first public computer in the area that was both available and accessible to the entire community and not under lock and key within a school laboratory.

Figure 2. A remote Hole in the Wall site, 40 mins drive from Jaisalmer, visited by two of the authors in December 2005

of the poorest of South African people. In 2002, the Meraka Institute of the CSIR, in conjunction with the South African Department of Science and Technology (DST), made a decision to implement a South African version of 'Hole In The Wall' in order to investigate the value of unassisted learning in a South African rural context. This marked the beginning of an extended and notable developmental project, the history of which is traced in the time line later in the chapter (Table 2).

The aim of the Digital Doorway project is, consequently, to better understand the issues behind using technology for the promotion of computer and information literacy in South Africa, specifically in the context of remote, unsupervised kiosks in various impoverished areas of the country, where target users have had little or no previous exposure to computers. What began as a purely investigative research project, developed into a combination of contractual implementation and on-going research. However, sufficient flexibility is permitted within the project for the contractual side not to 'dictate' the outcomes of the research, which can be a problem where funding for a project is provided by a body outside of the research organisation (Oates, 2006:160).

Table 1. Computer penetration ratios at schools in selected African Countries, 2006. From InfoDev 'Survey of ICT Education in Africa'

Country	No of Schools	Schools with Computers	Percentage of schools with computers
Egypt	26,000	26,000	100%*
Ghana	32,000	800	2.5%
Mozambique	7,000	80	1.1%
Namibia	1,519	350	22.1%
South Africa	25,582	6,651	22.6%

*Based on figures obtained from the Ministry of Education in Egypt, 2006.

Specific Objectives

The objectives of the South African Digital Doorway initiative can be described in terms of its initial research objectives and ongoing high-level objectives.

The initial research objectives (Smith et al., 2005) were to:

- Test the viability of unassisted learning as an alternative mechanism for attaining large-scale computer literacy in South Africa
- Determine the efficiency of the DD concept as a mechanism to enable computer literacy as well as information and service delivery in South Africa
- Determine whether potential users in a rural community in South Africa would use a PC-based outdoor kiosk without any instruction (unassisted learning)
- Determine whether a PC-based kiosk could operate without supervision in an outdoor location in South Africa
- Provide a platform for the evaluation of appropriate technology solutions and open-source applications

The ongoing high-level objectives are to:

- Narrow the 'digital divide'
- Provide technology for social inclusion (Warschauer, 2002)
- Prepare users, both young and old, for the information society
- Expose users in previously disadvantaged areas to computer technology
- Provide meaningful software and content to underprivileged communities

Research Method Overview

From the outset, the project employed a dual thrust of research and implementation. The designers were concerned not only with the development of a system, but also with an understanding of how that system was being employed in its context of use. The research goal was the creation of new knowledge particularly with respect to

Table 2. Digital doorway time line

1999	Dr Sugata Mitra of NIIT, India trials a mechanism to observe 'unassisted learning' of a computer system in his 'Hole In The Wall' (HOITW) project
2000-2001	Mitra's MIE concept proven to be successful in India (Mitra 2000)
2002	Digital Doorway project commences in South Africa with introduction of single-terminal device (Gush, Smith & Cambridge, 2004)
2002-2004	Similar findings on the success of unassisted learning validated in South Africa
2003	Migration to fully open source software begins with the introduction of the Debian operating system
2004	4-terminal DD housings introduced, together with improved open source based operating system
2005	Project expanded to 24 diverse sites around South Africa for comparison purposes
2006	Xubuntu 3-terminal diskless fat client solution developed
2007	Project expansion to 100+ three-terminal sites, software refinement, initial MESH network integration prototypes
2008	Further massification (deployment of over 200 units) and system refinement. Additional single-terminal desktop system designed. Protoype solar-powered standalone container system developed
2009	Five solar powered container systems to be deployed in rural locations. Formulation of an independent entity to manage installation and maintenance of DDs commences.

unassisted learning and technology deployment in impoverished communities in South Africa. Various research strategies and data generation methods were utilized with an underlying design-based research strategy. In the iterative research and development process, further insight was provided by consultation, surveys and community case studies. Data was generated through the use of questionnaires, interviews and observation.

Researchers chose an initial site based on high poverty levels and low computer penetration in the area. Site visits were performed in order to engage with the community and assess installation requirements. A prototype system was designed, constructed and installed on site. Software containing activity-logging functionality was installed. Researchers set up video monitoring equipment to record user activity at the site.

Data gathered from the application logging and video monitoring was analysed in combination with reports from field workers appointed to observe and interview community-based users. System designers performed post-installation site visits in order to assess the effectiveness of the hardware and software from a technology perspective. The team used the analysis and assessment data to improve the design of subsequent systems, as well as to inform upgrade decisions on the existing system.

Subsequent installations employed an 'on-line' user feedback mechanism to gather qualitative data from users. In addition to this, application-usage tracking tools were designed and implemented in order to gather quantitative data of broad trends in software usage. Field workers carried out further questionnaire-based and interview-based research.

Installation deployment was extended to cover a diverse range of sites, so that comparisons could be made between urban and rural installations, as well as between sites at varying locations (schools, community centres, police stations and so on). At a certain stage of the project, an external consultation company was tasked with performing case study research and system evaluation of a number of existing sites. Qualitative and quantitative data analysis from these case studies was used to further inform the design of subsequent systems.

Evaluation was also done in conjunction with comments, suggestions and requests from community stakeholders including users, teachers and municipal officials involved at the site. Many suggestions such as the final placement of the unit and possible design modifications (e.g. the addition of an external USB port) originated from the community.

Digital Doorway Time Line

Table 2 highlights the key milestones of the DD project from initial catalyst to current deployment status.

Table 3 shows the number of DDs installed in each province, and their type of location, as of January 2009.

THE DIGITAL DOORWAY UNWRAPPED

This section briefly describes the main components of the DD innovation, in particular the hardware, software and content.

While the 'One Laptop Per Child' (OLPC) project (Negroponte et al, 2006) aims to equip each child with their own laptop, DD terminals are designed to be social entities where a number of users congregate around a central device. Users benefit from peer learning (with users physically showing other users what to do) and individual interaction with the system. The design is based around a rugged, centralized hub of activity rather than individually distributed laptops (although collaborative peer learning is possible in both instances). Rather than individual ownership of a computing device, the DD emphasizes the need for community ownership of the equipment, the rationale being that 'a little needs to go a long

Table 3. Digital doorway distribution per province (July 2009)

Location: Province:	School	MPCC	Community Centre	Library	Fablab	FET College	Other*		Total
Eastern Cape	28	1	3	1			9		**42**
Freestate		1			1		1		**3**
Gauteng	4	1			2		1		**8**
Kwazulu Natal	6	6					4		**16**
Limpopo	27	6	7	2		4	5		**51**
Mpumalanga	27	1	4	2			2		**36**
North West	8	1		1	1				**11**
Northern Cape	22	1		2	1		2		**28**
Western Cape					1		2		**3**
Lesotho							1		**1**
Total	**122**	**18**	**14**	**8**	**6**	**4**	**27**		**199**

*Church, Post Office, Police Station, Mall, Butchery, Farm, Hospice

way', with higher utilisation when the computer is shared amongst members of that community.

Hardware

From the outset the team realised the necessity of building a computer housing that was rugged, robust and vandal-proof. From an initial single terminal unit, the housing developed into a 4-terminal arrangement for greater standing capacity, and finally a space-saving 3-terminal arrangement. The current 3-terminal configuration consists of a client/file-server PC and two diskless clients ('fat clients') connected via an Ethernet switch. The system includes a separate educational content server (containing 100 Gigabytes of additional educational content), a satellite dish (for downloads only) and GPRS (cellular network) modem back-haul (for status reports and log file uploads to a central server). Other hardware designs include the Desktop DD (single terminal designed for classrooms), DD for disabled users and Solar-Container DD.

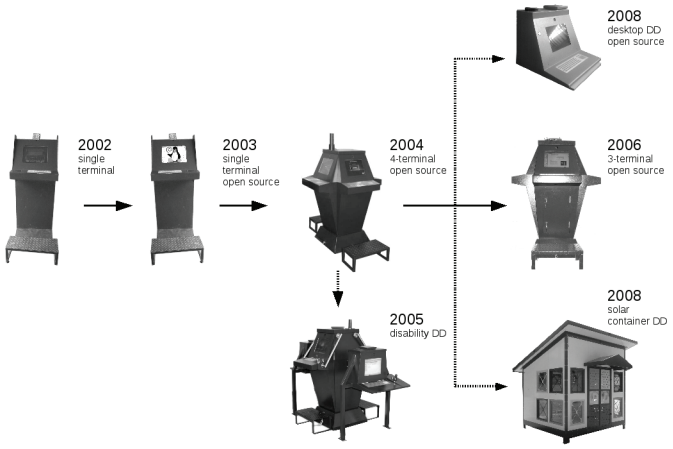
The development of the various DD housings is illustrated in Figure 4, which highlights how innovation in a real-world context led to refinement and improvement of the initial design.

The single terminal was limited in terms of the number of users, hence the move to the 4-terminal unit in 2004. This unit contained an HP441 server with multiple graphics cards and a customised operating system that could support four clients from one server, using Universal Serial Bus (USB) connections for the client mice and keyboards.

In 2005, there was a move towards accessibility, as the team designed a DD housing for use by the physically disabled. The housing had two low-level screens for wheelchair access, grab-handles to enable unsteady users to stabilise themselves, and large joysticks and oversized buttons rather than the usual touch-pad configuration.

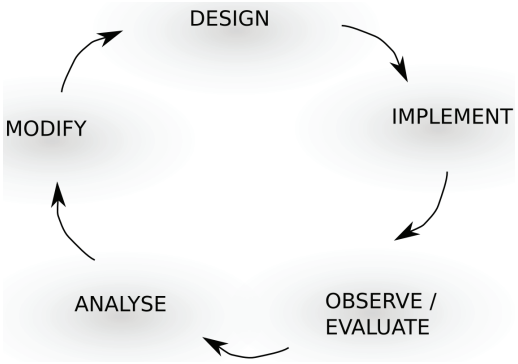
A 3-terminal server/fat-client configuration was designed in 2006 following the withdrawal from the market of the HP441 units. There was also a requirement to reduce the cost of installed

Figure 3. Digital doorway housings



equipment while maintaining the multi-terminal functionality. This configuration is the one being used currently. A 3-terminal configuration is viewed as optimal to reduce the floor-space required, while still allowing more users to access the machine compared to the single-terminal model. In a server/client setup, the clients can be low cost machines, without hard drives. The server acts as a file server for all terminals, with associated cost savings. See the appendices for more details of the hardware. A desktop single terminal version was, however, developed for use within a classroom where extra protection was required for the PC equipment.

Figure 4. Simple representation of the research and implementation process



In 2008, following the requirement by the main funding agent (the Department of Science and Technology) to install DDs in the most remote areas of South Africa, a prototype self-contained solar-powered container DD unit has been developed. This unit eliminates the requirements for both power and covered floor-space at the installation site.

Software and Content

In order to stimulate users to return to the DD, and in order to support the development of information literacy skills (through return visits to the computer), there is a need for relevant and engaging software and content that stimulates curiosity. Alessi and Trollip (2001) mention two aspects of curiosity identified by Malone (1980), namely sensory and cognitive curiosity, sensory curiosity being related to images and sounds encountered, while cognitive curiosity is 'curiosity about information' (Alessi & Trollip, 2001:288). According to Alessi and Trollip, frequent renewal of what is seen on the screen helps to maintain the user's attention, stimulating sensory curiosity. A game such as Tuxmaths that is installed on the DD embodies audio and dynamic graphics to maintain

attention, while simultaneously promoting the drill of solving mathematics tables.

Content and software on the DD is accessed either via icons on the desktop (high visibility) or via a customised Xfce XML menu structure / taskbar menu system (lower visibility). The menu is divided into two chief groupings, namely, 'Programs' and 'Resources'. The 'Programs' menu is subdivided into the categories of: Edutainment, Office, Internet, Games, Sounds and Miscellaneous. The 'Resources' menu is subdivided into: Simulations, Wikipedia, Agriculture, AudioBooks, Computers, Crafts, Fun, Heath and Safety, Literature, Realworld and Science. Content is stored in the form of binary applications, PDF documents, html pages, Java applications, and audio and video content files.

The Mamelodi DD (version 2) and subsequent models (4-terminal and 3-terminal) all employed one flavour or another of open source Linux software. The latest 3-terminal DD PCs employ a modified Ubuntu Linux OS with the Xfce display manager and a distributed client system, where each client becomes an independent terminal, but content is shared among all terminals. The inherent security of Linux is employed to prevent unauthorized modification of system-critical files. User-generated content saved within a home directory is modifiable by the owner of that directory only.

Prevention of desktop degradation is crucial in remote unmanaged projects of this nature. Scripts are run each evening to clean up guest (non user-generated) accounts, restore the look of the desktops, and clean up the guest directories of all extraneous files.

Various kiosk mode options were implemented in the windows manager. The options also prevented the starting up of shell scripts, locking of the screen, moving of toolbars, execution of the command line 'run' command, and the starting of a new session. This was necessary to keep the system usable.

For all the 3-terminal systems, scripts were developed to wrap each application in code that could detect when that application was accessed (see later section on application usage). Other scripts manage the compression and transmission of the log files to a centralised server accessible by the researchers.

As in the case of the hardware design, the software went through various iterations and refinements, in line with an action research or design-based research paradigm (see next section). As illustrated in Figure 9, the DD is addressing a real need in a natural setting and, as such, the content has the potential not only to inform, but also to transform the community of users.

DESIGN-BASED RESEARCH

What is the underlying research design of the Digital Doorway? The answer to this question is intrinsically related to the DD's main purpose. Is it an implementation of the emergent discipline of community informatics (CI) or is it first and foremost an educational system? If the former, then its research design requires a theoretical foundation that integrates and directs CI's double agenda of information systems (IS) problem solving and practical community problem solving (Stillman & Linger, 2009). If, on the other hand, it is primarily a technology to support learning, then it requires grounding in a research methodology that emanates from the educational sciences. A study by de Villiers (2007) on interpretive research models for informatics takes cognisance of Walsham's (1995) work on interpretivism and addresses design-research and development-research which, de Villiers posits, are implemented in IS as design-science research and in educational technology as design-based research.

That said, one returns to the issue of the DD's main vision. Although it has potential for community-based add-ons, such as community bulletin boards and community specific content generation facilities, its prime purpose was, and still is, the support of learning. Hence an educational

technology research design is more appropriate than a CI- and IS- based conceptual grounding.

The concept of unassisted learning in rural South Africa as set out earlier in the section on objectives, i.e. learning without any external instruction whatsoever, is a new and challenging research area. Critics such as Warschauer (2002), have reacted against Mitra's concept of 'minimally invasive education' by calling it 'minimally effective education' due to the fact that it does not deal with important factors that play a role in acquisition of access to ICT, such as social resources (e.g community support). These aspects had to be included in the research.

The DD project has a dual thrust, involving both a research focus and an implementation drive, as in action research with its action outcomes and research outcomes (Bjerknes, Ehn, & Kyng, 1987; de Villiers, 2007; Sandberg, 1979). Through real-world experience, the developers of the DD learned the value of explicating a research design. This section highlights some of the key aspects in the research side.

The project followed an iterative process of *design, implement, observe/evaluate, analyse, modify, redesign, implement, observe* as shown in Figure 4.

As the practices of the DD progressed further to meet real-world needs, the iterative research processes became a series of cycles. The underlying research paradigm moved beyond classic action research to become an example of design-based research (DBR), an emerging and maturing research design increasingly used for studies involving the development of innovative educational technology (Barab and Squire, 2004; Design-Based Research Collective, 2003; Wang and Hannafin, 2005).

Design research owes its origin to Herbert Simon, the Nobel laureate (Simon, 1981), who distinguished between the *natural sciences* and the so-called *design sciences*. Natural sciences relate to natural phenomena such as those described in physics, astronomy and anatomy, where descriptive theories and formulas explain phenomena in terms of laws and relationships. Design sciences or 'sciences of the artificial' relate to man-made objects and phenomena, where prescriptive theories and models represent goals to be achieved and procedures to achieve them. They are applied sciences, characterized by problem-solving processes, invention, construction, and evaluation of artifacts or interventions. Examples are medical technology, engineering, architecture, product design, and education with its theories and procedures. Design science led to *design research*, which in the context of e-learning and educational technology, is termed design-based research (de Villiers, 2005).

Education and learning are characterized by complex problems, which call for inventive solutions, and the associated construction and evaluation of artefacts or interventions. DBR terminology evolved from the 'design experiments' of educational practice conducted by Brown (1992) and Collins (1992), through 'development research' (Reeves, 2000; van den Akker, 1999) and 'developmental research' (Richey, Klein and Nelson, 2004) to consolidate at 'design-based'.

Features of Design-Based Research

Barab and Squire (2004:2) define DBR as an iterative 'series of approaches with the intent of producing new theories, artefacts and practices that account for and potentially impact learning and teaching in naturalistic settings'. It is suitable for problems in ill-structured environments with complex interactions. The experimental generation of new prototypes highlights the roles of cognition, intuition, creativity, inquiry and teamwork in solving problems and generating new knowledge. Claims about the functionality of a design are evidence-based, emanating from natural settings. Knowledge about an artefact thus evolves in context, and even by trial and error. In the context of e-learning technologies, Wang and Hannafin (2005) describe DBR as being:

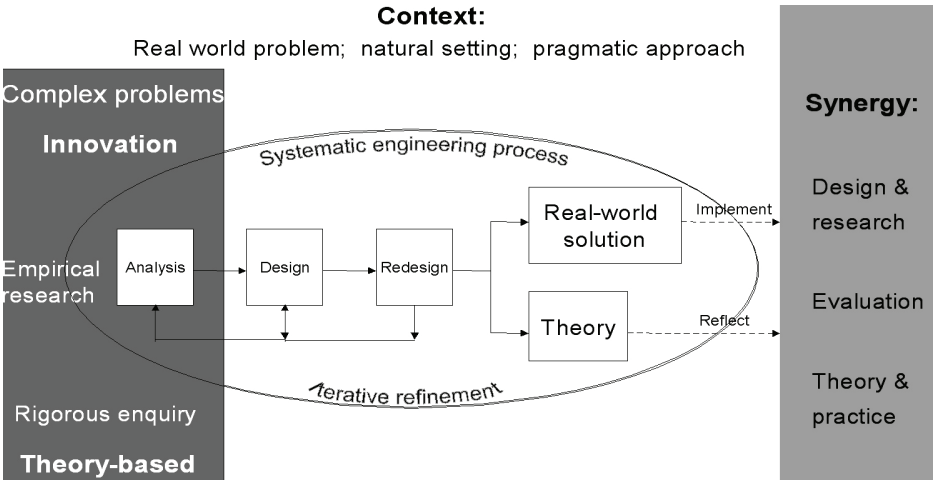
- *Pragmatic and theoretical*: extending and generating theory while producing principles to inform and improve practice.
- *Grounded*: design of 'interventions' in real-world contexts; ideally, theory-driven, based on appropriate learning or instructional theory/ies.
- *Interactive, iterative and flexible*: designer-researcher-participant teamwork; iterative cycles; formative evaluation and usability analysis; generation of evidence to guide revision and improve design; initial prototypes.
- *Integrative*: hybrid research methods using data from multiple sources.
- *Contextualised outputs*: results connected to research setting; the design principles generated are contextually-sensitive.
- *An extension of existing methodologies:* e.g. an extension of action research

Dede (2005) expresses an intriguing concern about combining designs from the 'skills of creative designers' with research by 'rigorous scholars'. Where designers have free reign, there may be design creep as exploratory interventions evolve into full-scale initiatives instead of being bounded research. Driven by technology and not by need, a technological guru might champion a particular solution and look for situations to apply it. Pure researchers have a contrasting weaknesses called 'design constipation', as they look for designs that offer straightforward data collection and analysis, so they can retain analytic and methodological frameworks at the expense of effective, scalable and sustainable innovations (Dede, 2005). DBR can bridge this gap.

DBR fosters cross-disciplinary work - for example, in the DD project, engineers, educational researchers and sociologists were involved. This collaborative approach leads to insights in unpredictable real-world settings (Kelly (2003). In complex and ill-structured environments, the design of artefacts and the development of theories proceed concurrently, informing each other. DBR aims to influence practice with real changes at local level and to develop tangible applications that can be adopted elsewhere, although caution must be exercised in transferring context-specific claims.

Figure 5 shows the features and themes of a DBR research design. The central model in the oval with iterative processes and evaluative feedback loops, represents development research which preceded DBR (Reeves, 2000; de Villiers, 2007). The surrounding infrastructure shows how DBR has developed further. The surround depicts

Figure 5. Model of design-based research (de Villiers, 2007)



the real-world setting and its complex problems (left side) that can be addressed by innovation, empirical research and experimentation. Synergistic consequences of the reflective processes of the model (right side) are the joint advancement of design and research, and similarly of theory and practice as DBR – implemented here by the DD - sets out to change situations.

Features and Themes of DBR as Applied to the Digital Doorway

Features from the meta-analyses and reflective studies of Cobb, Confrey, diSessa, Lehrer, and Schauble (2003), the Design-Based Collective (2003), Barab and Squire (2004) and Wang and Hannafin (2005) are tabulated in Table 4 against their implementations in the DD. The right-hand column also refers to community contributions, indicating the role of users in participative research.

DATA COLLECTION AND ANALYSIS: QUALITATIVE AND QUANTITATIVE

As mentioned earlier, research data is gathered in multiple ways:

- Observation and interviewing of participants by the core DD team
- Appointment of sociologists and dedicated teams (out-sourced) to observe and interview participants, both orally and through the use of questionnaires / surveys
- Implementation of software mechanisms to capture user activity and demographics
- Implementation of software mechanism to enable users to provide feedback on their experiences.
- Video analysis of data captured via installed security cameras
- Initial assessment and evaluation of the DD installations focused on the following (Smith, 2005)
- Who used the DD, e.g. what age groups and genders?
- How many participants were present at a specific time?
- How long did they stay?
- What activities did each participant or collaborative group of participants do?
- What were the reactions of spectators?
- In each case, was there evidence that learning occurred?

Results from Observations at the Cwili Site

The following observations, taken from Smith (2003) are important in providing a general impression of activity at the very first DD. This DD kiosk in Cwili was installed and became operational without any announcement or instruction in November 2002. It was officially opened by the Minister of Science and Technology in December 2002. Initial observations commenced on 22 November 2003, and were performed by Prof. Denzil Russel, professor emeritus of Adult Education at the University of the Witwatersrand. Prof. Russell, who was staying within a few kilometres of the site, was well positioned to carry out this observational research, which included informal interviews, analysis of computer captured data, group discussions with users and non-users and systematic debriefings of the community champion and others informants. Prof. Russel made the following observations:

- Once installed the kiosk was used immediately – even during installation the interest of children, in particular, was intense.
- The kiosk was used almost continuously from as early as 4:15am to around midnight and even later.
- Group size varied: normally from 4 to 12.
- There was intense vocal activity, music and constant jostling for position.

Table 4. Summary of design-based research models and associated digital doorway features

Features of DBR models	Elaboration	As implemented in Digital Doorway
Real-world complex problems	Design theory addresses complex problems in collaboration with practitioners/ educators.	Complexities: remote and rural locations; lack of infrastructure; school teachers not computer literate. DD enthuses some of them and they in turn encourage learners to use it.
Problem solutions grounded in pre-existing theories,	Where appropriate theories/principles pre-exist, design should be theory-driven, along with technological affordances, to propose solutions to the problems.	Minimally invasive education / unassisted learning in India through the hole-in-the-wall experiment has been shown to be successful (Mitra, 2000). Children's natural curiosity motivates learning. Peer learning is a valid form of learning (Boud, D. 1999). Both curiosity and peer learning are clearly in evidence in the use of DD. Requests by users have contributed to extensions to DD features, making the users co-researchers and 'co-developers'.
Innovation	Underlying innovative approach (Kelly, 2003). DBR should investigate less-common practices and generate technological support; design of innovations, novelty, interventionist approaches.	Solution unique to Africa in terms of rugged, vandal-proof computer housing when compared to typical lab-based computers. Multi-terminal − social interaction occurs alongside learning. Fully Open Source Operating System and Content. HW and SW innovations as detailed elsewhere.
Engineering	Systematic methodology that involves designing and studying means or artefacts of learning.	Usage tracking tools used to study learning that has taken place. Statistics gathered on a site by site basis, hard data available. Subjective, qualitative data accumulated through interviews and observation.
Iterative design	Cycles of design, enactment, analysis, redesign.	Following on from first installation in Cwili, hardware and software underwent numerous design changes and improvements based on user co-participation via interviews. Further feedback obtained from observation of user interaction. Sites upgraded when major software releases are available.
Context and environment	Research studies in context, i.e. in naturalistic settings; use of artefacts/ interventions in the real-world; theories also to be contextualized; Responsive to emergent features of the setting (Kelly, 2003).	DDs are located in designated communities where a need is identified. Data gathered on site. Participative workshops involve community-based stakeholders, who offer suggestions. Authentic use in real communities.
Empirical research	Studying tangible, real-world products, which ideally, should be usable elsewhere, i.e. influence on teaching, learning and training practice. Data collection and analysis.	Data collection through observation of learners and video data, interviews and surveys. Instruments: automated logging/ recording of usage statistics. Knowledge obtained from these systems transferable to similar installations elsewhere.
Participants as collaborators	Participants are not merely subjects, but can be co-participants in the research.	In day- or half day workshops, community leaders and, in some cases, other community members joined Meraka researchers as co-participants to discuss aspects of DD implementation and usage.
Refining the artefact / system	Using formative evaluation to derive research findings; design and explore artifacts, environments, etc. with rigorous inquiry methods to refine them and define new design principles.	Hardware progression from single terminal to 4-terminal to space-saving 3-terminal. Further work led to a DD for disabled users and a desktop variety. Software refined based on experience gained from previous versions. Content increased to better meet the needs of the users.
Output products: 1.Useful real-world products 2.Development of theory	Real-world products: technical and methodological tools; frameworks; interventions; even curricula. These offer immediate value in the environment of use. Theories that are generated, evaluated and refined in a reflective cycle. They provide a set of theoretical constructs that can be transferred and adapted beyond the initial environment.	Success of initial prototypes led to rollout of more DDs. Poor electricity supply at some sites and unsuitable venues led to solar-powered DD Container. Desktop single-terminal DD. Production of a DD Software DVD. Teachers (e.g. Gatang high school) realised the value of the DD as an information resource, sending pupils there to do homework research. Theories developed around effective and ineffective systems (deployment strategies) and dealing with the rural context in the design of technology.

continued on following page

Table 4. Continued

Pragmatic	The theories developed should do real work and be supported by evidence-based claims about learning.	The success of the DD in teaching basic ICT literacy has resulted in the deployment of multiple machines, nation-wide. Evidence seen in the feedback received, and social assessment of users.
Synergy	Design and research; theory and practice; are advanced concurrently.	Project has a deployment and research phase, mutually feeding into and affecting each other.

- Random exploration was initially very prominent but this rapidly progressed to confident deliberate application.
- Peer learning was evidenced, as township children taught each other basic computer functions, including the ability to drag icons, re-arrange windows, open applications and access the Internet (available for a limited period on the Cwili and Mamelodi DDs).
- The relevant touch pad computer skills were rapidly acquired by the 7-16 age groups.
- The 7-16 age groups also acquired some general knowledge and competence in English.
- Estimated 8,300 user-visits in 3,3 months (regular user-visits 60%; occasional 40%).
- Ages of users ranged from 7 to 56 (most in the range of 10-19). (see later section for similar results from other sites)
- Gender distribution about equal, but more girls amongst regular users. (Note that in other communities, male:female ration was approximately 3:1)
- The majority of users during daylight hours were school children. Young adults (20-30 years) tended to use the computer very early in the morning and in the evening.
- A small group of users determined how to keep the computer to themselves by using a piece of wire to switch it off through a concealed hole at the side of the kiosk.

Results from Observations at the Mamelodi Site

The Mamelodi DD, installed in 2003 was the closest to the researchers' base at CSIR, and therefore the easiest to visit. This was a single terminal machine. It took a while for the news to circulate that the DD machine was for the use of anyone in the area. This is understandable, as very little was done in the way of promotion other than by word of mouth. The terminal was initially installed at the council offices, and later moved to a high school.

On average, between 15 and 30 users accessed the kiosk per day. The ages of users ranged from approximately ten years old to 40 or 50 years old (as noted from video observation). Predominantly young adults and boys seemed the most interested. Typically there were from one to three users at any one time, although on occasions there had been as many as eight users at the same time.

Initially, many users were curious to look at the machine and perhaps touch a few keys. About one in five of the people who entered the room where the terminal stood, stayed to really explore the computer system. Within a few weeks, most of the applications had been accessed, with users playing the educational games, typing words using the text editor, using the Tux Paint drawing application, accessing the Internet and capturing their image from the webcam onto file.

Much of the activity observed, involved navigating the cursor around the screen, clicking on various icons, and scrolling through the menus. It was obvious from the erratic nature of this be-

havior that most of these activities were new to the users. Most users had a tendency to minimize rather than close a particular application when they lost interest in it. This resulted in the system eventually becoming overloaded with open applications, and on more than one occasion KDE - the desktop environment - became unusable. It became necessary to remotely close the applications, and instigate a daily forced system reboot.

Further Observations from Early Sites

- The younger children were the most spontaneous participants. Their groups were generally larger than those of young adults and older adults, generally up to twelve in size. When children used the DD they were excited and noisy, interacting with each other much more than the older users. They were much more comfortable squeezing in front of a single terminal to work together.
- The time users spent at the DD depended to a large extent on the total number of users at a single time; whether they could use a terminal on their own; their specific purpose for using the DD; as well as their age. Users who had a workstation to themselves, older users, and users with a specific objective seemed to stay longer than children or those just exploring. Users typically stayed at the DD for 30 minutes to an hour at a time.
- Spectators also participated actively in the proceedings. Many of them moved from one workstation to another to see what the various participants were doing. They made comments and gave inputs, based on what they observed at the other workstations.
- Peer learning was evident in that especially children showed one another what to do. Young and older adults were also comfortable learning from each other and asking for assistance, albeit less frequently than the younger users. Researchers concluded that it was clear that the users were learning without, or with minimal, help from the outside. Co-operative learning took place most of the time, usually because some of the participants had previous experience with computers. Less confident users would watch while other users interacted with the DD.
- Peer learning amongst the younger children was more a matter of competition than collaboration, whereas collaboration seemed to be the learning method of choice for young adults and older adults. All participants rapidly acquired the relevant keyboard and touch-pad skills. Children, especially, seemed content to explore until they achieved the desired outcome, rather than ask for assistance.

The Collection and Analysis of User Feedback, Demographic Data and Application Usage Statistics

In order to analyse user feedback, demographics and usage at the sites more accurately in the subsequent 3-terminal installations, two mechanisms for collecting this data and transmitting it back to a central server were designed. The first involves a simple form accessible inside a web browser on the DD where users are encouraged to provide feedback about their experiences of using the DD. Users type a message into the text window, optionally enter their name and contact details, and the message is stored locally for transmission back to a central server once a day. Secondly, for the collection of empirical demographic and usage data, the following sequence of events occurs:

- User chooses between guest account login, own login or ‘new user’ creation
- If new user creation is chosen, user takes action to create own user space

- User enters details (age, gender etc.) on form
- Details are added to user registration file on DD server
- File is updated once a day to communications server
- Applications on DD are launched from menu using a wrapper script (tracker)
- Wrapper script writes start time, application name and arguments to user-specific log file
- Log files are compressed together and copied to communications server once a day
- GPRS modem is used to transmit compressed log files and registration files back to central ftp server for download and analysis.

Feedback from Users

Qualitative feedback received from users has been categorised into positive, negative and suggestions. Encouragingly, when this feedback was reviewed, 49% (66 responses) comprised positive comments, 46% (63 responses) suggestions or requests and only 5% (7 responses) comprised negative comments. Examples from each category are given below.

Positive:

'Dear people of Location. Do not mass [authors: 'mess'] with this computer because it can work it help us to find important things that we don't do anything that make this computer stop to work. Please people do something best for your children. MR. Nothoriuos.' - (Cwili, 2002 – written in an electronic note saved on the Digital Doorway itself)

'hi i'm enjoying it a lot coz there are many things i''ve learn. and i'using it to find info.about how people were living long time ago.&finding out about what happening around us "ya" oh! i nealy fogort your science is absolutly great there are many things i can say about your computers thnx a lot' "Duma" - (Ntshongweni School, May, 2007)

Suggestions:

'The learning contents that make it easy for learners to doassignments, the health contents messages to the youth about HIV and Aids. However it is very difficult for people to seek contents and transfer them into books standing. We therefore recommend that this DDW be fitted with a USB slot for esy transferance of learning contents since this DDW IS getting to be more and utelised for games.' - (Elandskraal MPCC, February 2007)

Negative:

'I am using this Digital Doorway for playing games and many other things which this machine does have. The only problem is it is stationed at a place which we usually do our home-work during free periods and many students make a lot of noise. So please may you change place?' - (Letaba College, February 2007)

Results from Quantitative Data Analysis

The results below (Gush, 2008) are based on data gathered from 75 sites around South Africa. Given that data is being collected from so many sites, each consisting of three DD terminals and multiple users per terminal, the amount of data is extensive. Numerous social insights and conclusions can be drawn from the analysis of this data. Some broad results have emerged from this process and are highlighted in the ensuing discussion.

- Sites analysed: 75
- Time period: January 2007 to January 2008
- ***Registered users***
  - Total self-registered users: 3,896
  - Average number of self-registered users per site: 52

- ***Registered user versus guest user application launches (number of times a program is run)***
    - Registered users: 52,409 recorded application launches
    - Guest users: 468,433 recorded application launches

Thus, only 11.2% of activity is generated by logged in, self-registered users. Either most users have not registered their own user names or they do not log in with them or use them. Reasons for this may be the added level of complexity and computer skill required to create one's own user name, or the desire for anonymity. Logging in as a guest user is a one-step process (entering the guest login as indicated on the screen), whereas logging in as a registered user for the first time is a three-step process (typing 'new' to reach the user creation screen, entering details, logging in with the newly created user name and password). No benefits of creating a user name are indicated on the login screen, further encouraging the user merely to log in with a guest account.

Registered User Demographics

The following results were generated from 75 sites with data up to January 2008.

- **Gender:** Sixty-nine percent of all registered users indicated their gender; 31% did not. Of this 69% who specified gender, the following results emerged: Male: 75%, Female: 25%. These results vary from site to site. At a DD located in a high school exclusively for girls, feedback was mostly positive and utilisation was high, therefore the high percentage of males reflected in these general statistics is unlikely to be as a result of disinterest by females. No research was conducted to ascertain why the discrepancy exists, but it could be due to males being physically stronger than females, thus pushing them out at congested terminals (see Figure 6).
- **Age Distribution:** Plotting a graph of age (in years) on the x-axis versus number of registered users on the y-axis, yields the results shown in Figure 7.

The high percentage of registered users in the 10 – 25 age range can be attributed to the following factors:

- a number of DDs are located in schools and higher education facilities.

Figure 6. Proportion of male to female users

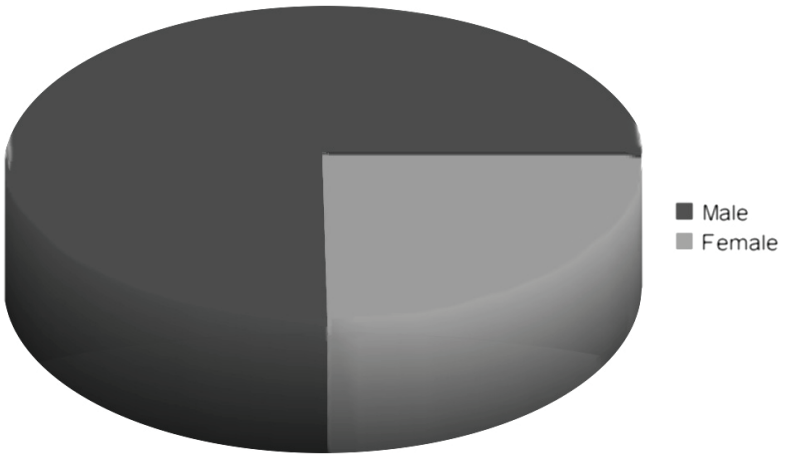
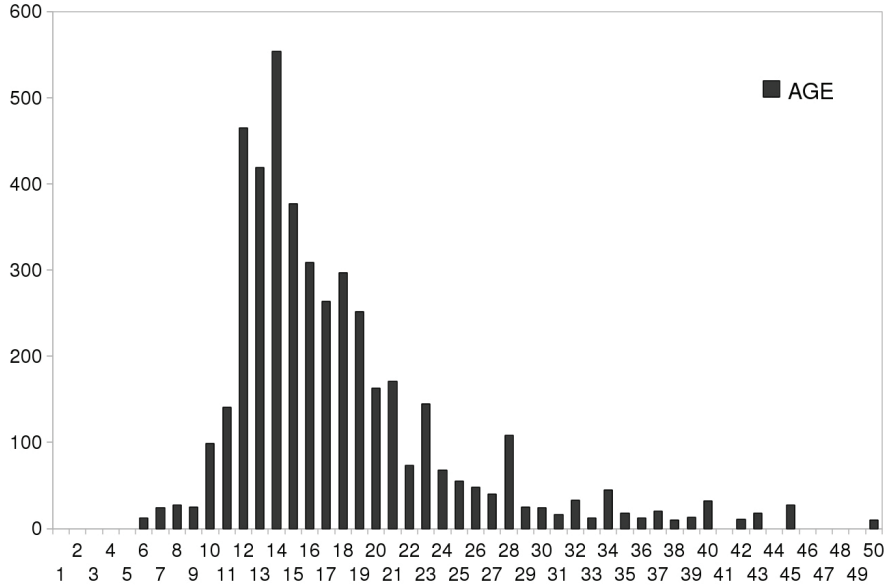


Figure 7. Age distribution of registered user



- young people are not afraid of new technology
- young people have more spare time to spend at the DD
- details of the self-registration process (the source of these results) are shared between youngsters more than adults, as the youngsters are generally more sociable and keen to share their experiences

Application Usage

Application usage data was collected from 165 sites and reflected user activity from the various installation dates until July 2009. The fifty most popular applications on the DD were identified. Grouping these results into broad categories gave the results shown in Figure 8.

While much application usage was seen to be the launching of games (such as the very popular Gnibbles), there was also a healthy amount of use of the educational applications and resources provided, such as Gcompris (an educational suite), Wikipedia and the science simulations. The platform needs to be seen as entertaining as well as educational, and not just another classroom resource, hence the pragmatic decision to retain games as part of the content.

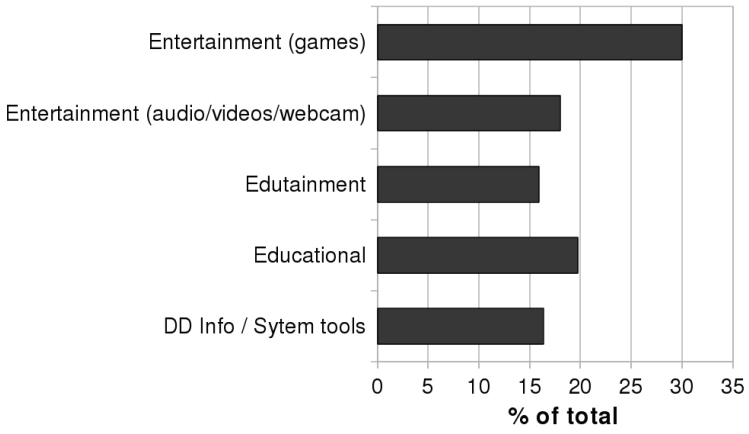
For examples of typical user sessions at the DD, please refer to 'Snapshots of user activity' in the appendices.

FINDINGS FROM PARTICULAR SITES

Mamelodi

One of the earlier Digital Doorway sites that illustrated both the good and the bad aspects of an urban site was the one located in Mamelodi, just north of the city of Tshwane (Pretoria). Mamelodi is a residential area inhabited by close to one million people, with an unemployment figure of approximately 55% (Revised Tshwane Integrated Development Plan 2020, 2009) and many others earning very low wages. The DD terminal was housed inside a small room with a single entrance from the street, adjacent to the municipal offices.

Figure 8. Categorised application usage



The room was modified by blocking up the door facing the municipal site and breaking out a new outward-facing door. A small roof was constructed over this door, and an antenna mounted on the roof of the building to allow connectivity with the nearby CSIR campus in Pretoria. Inside the room a security camera was mounted in one corner to record live video data of the activity at the DD. This footage could be analysed at the CSIR.

The site location was favourable in the following aspects: first, it was located in a busy street with a high density of pedestrian traffic passing by, either on their way to the municipal offices, nearby train and taxi station, or to the local street vendor selling various items. Second, parents could leave their children at the DD while they visited the municipal offices

A few months after installation however, some undesirable aspects of the site emerged: The closed room with single door entry meant that some users, especially girls, did not feel safe using the computer inside. Furthermore, the room became a shelter during rain and from time to time the home for the homeless who unfortunately left it looking and smelling bad. The provision of a trial Internet connection (via a wireless link back to the CSIR campus) resulted in the terminal regularly being used exclusively by young adults and older teenagers who used it solely as a 'free Internet cafe', often searching for content of questionable value. From the logs it became evident that when the Internet was down, the system was used by a much wider range of ages who accessed the wealth of content cached locally on the DD. Finally, an incident was caught on film where a certain user found his way to the back of the computer and cut the cable leading to the security camera. After this point, no further video data could be gathered!

Subsequently the DD was relocated to a high school elsewhere in Mamelodi where further research could be conducted in a different context.

Pampierstad

The rural town of Pampierstad in the North West Province has a population of between 10,000 and 20,000 people (depending on radius). The DD here was an example of a successful location from a site champion perspective. The site champion (a local librarian) took ownership of the device, demonstrating his willingness to make the project a success by ensuring that a protective cage was built around the DD and by organising that plants be used to decorate the area inside the cage (see Figure 9). The librarian also requested that the DD be connected to the library printer, and would occasionally complain that he had to chase people out of the cage and library complex at 5pm when

Figure 9. Children at the Pampierstad digital doorway

the library gates were locked, an indication of the popularity of the DD.

The Pampierstad DD helped highlight the need for an enthusiastic site champion at each site.

FURTHER DISCUSSION AND FINDINGS

Hardware and Maintenance

The long-term success and sustainability of each Digital Doorway installation depends on many factors.

System ruggedness is a key requirement for unsupervised installations such as these. Only after a number of iterations did the degree to which this was true become apparent. The choice of keyboard is a good example of the many hardware aspects that underwent scrutiny, research and refinement as the project progressed. The initial choice of plastic keyboard, installed in Cwili, at the first site, did not last more than a week as enthusiastic children repeatedly plucked off the keys of the keyboard to play with them and take home as souvenirs. A second imported 'industrial' keyboard did not last more than a month or two, before the waterproof silicon coating over the keys literally disintegrated due to repeated use. The next version was a metal keyboard with metal trackball. The keyboard proved to be fine, however one enthusiastic user managed to insert a ten cent piece between the trackball and trackball housing, a feat the designers claimed was impossible until they saw the actual keyboard. Only after installing an expensive ($400-$500) metal keyboard with reinforced touch-pad, did the keyboard woes subside. The cost of the keyboard had to be weighed against the even higher cost (and effort) of repeated visits to replace a cheap keyboard.

On installation, a particular person, a 'champion', in the community must assume responsibility and accountability for ensuring the success of that DD. This responsibility must be maintained either through a paid incentive or due to the passion and commitment of this particular stakeholder. Where a community has been identified to receive a machine (top down approach), a paid incentive may be necessary. Where a DD has been requested by a particular school or community (bottom up approach), there is usually an enthusiastic person behind this request, who will ensure its ongoing success.

System failure or downtime must be reported immediately to one central call centre, rather than to the individual cell phone numbers of maintainers. In the latter case, staff may leave or change job responsibility or go on leave, and the fault is not picked up. Fault reports must be maintained so that trends can be analysed and preventative measures implemented.

In the areas of greatest poverty, the cost of the electricity to supply the DD can become an issue. Units get switched off to save electricity. This problem needs to be dealt with in a structured way upfront, as part of the installation process for each site. Where the installations are largely driven by national government, the local municipalities need to be mandated to provide an electricity budget for the machines. In schools, provision should be made for this increased cost, in the running budget of that school.

The answers to the following questions should be determined before equipment installations:

- Who owns the equipment?
- Who is responsible for its continued success?
- Who is responsible for electricity costs?
- Who will provide maintenance?
- For how long is the equipment expected to run?
- What procedure should be followed in the case of a system failure?

Community Stakeholders

For leaders and stakeholders in the community, it is important that the perceived value of the device is understood. Without this, there will not be the motivation to ensure its continued operation. In order to achieve this, time needs to be spent with community leaders before each installation. Although time consuming, this will be time well spent, as it will save money in the longer term. The machine is then perceived as a valuable asset to the area, and is consequently better managed and cared for, reducing maintenance costs.

One potential solution to some of the abovementioned problems is to ensure that the local municipality or local government is involved right from the outset. The municipality can then take responsibility for ensuring electricity supply and promoting the DD. This will 'institutionalize' the DD, and allow local authorities to allocate a portion of their budget to looking after the DD.

Instead of having a 'Community Champion' who has been trained merely to monitor indicators and provide feedback, it may be preferable to empower several local residents to do more detailed first-line fault finding, training them in the diagnosis and rectifying of basic errors (such as the need at times to reboot the uninterrupted power supply (UPS) after a lengthy power failure).

In regard to conducting research in similar community-based projects, it is important to ensure that community members become 'co-researchers' in the exercise, rather than mere data sources. This can be achieved through the following mechanisms:

- ensure that there is communication with the community leaders from the outset of the project
- allow typical user comments, suggestions and criticisms to inform both the design and implementation of the technologies
- use interviews, questionnaires and meetings to engage with the community and ascertain their expectations and needs; and
- be sensitive to cultural differences between those conducting the research and those in the community

Holistic and Tangible Solutions

Theory needs to be applied in real life situations. Unless words and ideas are transformed into actions, they remain powerless to change people's lives. A successful project will invariably lead

to an increase in sites, and this presents its own challenges, requiring an enthusiastic core team, and partnerships with all the necessary human resource elements (communities, hardware suppliers, installation and maintenance contractors, funders and social researchers). In order to deal with the many complexities and challenges that arose, the DD team had to address problems holistically, addressing both social and technical issues. Solutions in a social context were often site specific, while technical challenges remained fairly consistent from site to site.

A critical success factor in this project was the iterative construction and installation of tangible solutions. From the very beginning, the physical DD prototypes provided a concrete object that served as a catalyst for healthy discussion. Somehow, being able to demonstrate a real model, and talk around that, rather than having to rely on documents and words only, produced enthusiasm in potential stakeholders that would have been absent otherwise. These discussions were supplemented by photographic and video presentations that further brought home the realities both of the needs in the communities and the potential of the DD to meet those needs.

Controversies

Invariably, when dealing with people, certain controversies arise as to the correct course of action. We highlight some of these issues.

Politics and Language

The impact of politics was unavoidable – community politics, regional politics and national politics. What hindered on the one hand, helped on the other. Although community engagement slowed the process down, community buy-in ensured a more successful site. Securing a suitable site often involves lengthy discussions with a number of different leaders in a community, however, if there is full support for the project, the long term success is ensured.

While national politics added red tape, the availability of funds to install more DDs was crucial. However, issues arose around the boundaries of responsibilities. It is important, right from the outset, to define where the national government's involvement ends, and where the local or municipal government would be expected to take responsibility for the site. This is more important in installations such as community centres and recreation sites than schools (where the school typically takes ownership and responsibility for the unit).

The availability of content in all official languages of South Africa is often a contentious issue. The reality is that most content is available in English only, and translation is a lengthy and costly process. Where possible, content is made available in other languages besides English. For example, the DD on-site tutorial front page was translated into Afrikaans, Zulu, SeSotho and Venda.

Provision of Free Internet Access

Another controversial issue is the provision of free Internet access. This was tested at the Mamelodi site, with interesting results, as mentioned earlier. The high cost of Internet access in rural South Africa also made it unsustainable (the South African government does not sponsor Internet connectivity) and thus the decision was made to cache as much content as possible on site and not provide Internet access. As a consequence, the user is not able to experience the full power of social networking sites, email and access to on-line search engines, educational sites and other websites. Various ideas for overcoming the undesirable surfing activities and the high cost of Internet access have been proposed. One feasible alternative is to provide user-paid GPRS Internet access with a content filter.

Housing Colour

Seemingly innocuous design decisions and aspects of the human-computer interface often proved to be controversial, for example the choice of colour of the DD units. The point has been raised that the colours should be chosen to appeal to both boys and girls. From another perspective, funding parties preferred a colour scheme that reflected the colours of their organisation. No research was conducted to help determine the most suitable choice of colour for the housing. It has been noted that the original royal blue seems to show less dirt than the later rescue orange.

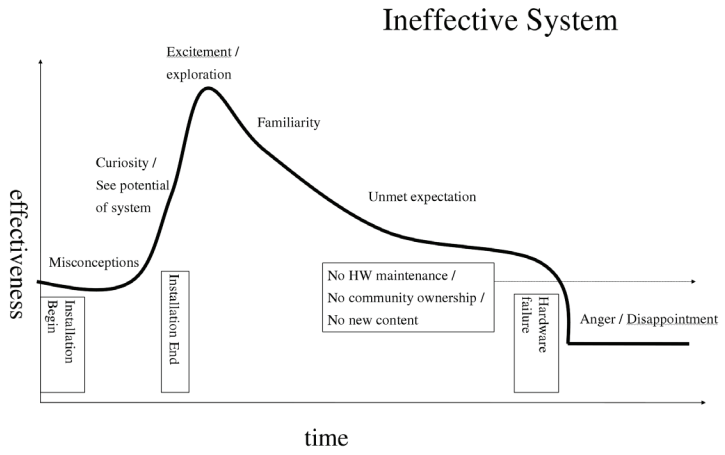
Challenge: Ensuring an Effective Installation

This section proposes two possible outcomes for an installation based on our experiences to date. The first is the 'Ineffective System' and the second is the 'Effective System', with effectiveness being defined as the ability of the DD to deliver on the expected goals of the project, namely: basic ICT literacy training; information literacy training and provision of information; and community enabling. Effectiveness can be measured more by qualitative than by quantitative means, for example, observing how users without any prior knowledge of computing, learn to navigate their way around a computer system and perform basic operations; access information; maintain attention and engagement; and eventually gain the expertise to track down information on a particular topic.

Ineffective System

In an ineffective system, see Figure 10, the device is installed in the community and, possibly following some apprehension from some of the community members about the purpose of this strange new box, excitement builds up about having access to a computer for the first time. In the weeks and months after installation, the community becomes familiar with the device and if there is no updating of content - possible via a satellite download - then users become bored and interest wanes. If there is no hardware maintenance, eventually a component will fail and the community is left with a white elephant. The resulting disillusionment of community members leaves the community in a state worse than before the device was installed.

Figure 10. Graph showing the increase followed by a decrease of effectiveness over time (scenario 1)



Effective System

In an effective system, see Figure 11, the content is updated regularly, and proper system maintenance is carried out. Failing components are repaired or replaced within a few days of failure. The community is involved from the outset and users take ownership of the equipment (cleaning the device and surrounding area, advertising the fact that the DD exists, informing maintenance teams of failures). The level of computer literacy of users increases. Users regularly use the device both for learning and fact finding. Peer learning takes place as knowledge is transferred between users. Proficient users are eventually able to generate their own content and the device is an undisputed boon to the community.

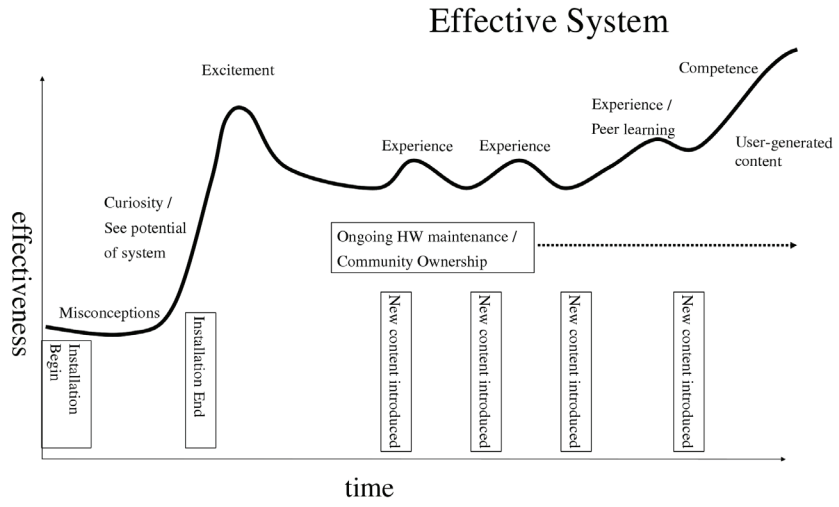
Experience has shown that the DD sites which become ineffective over time do so due to two main reasons: firstly, hardware failure - due to a lack of adequate system maintenance and a lack of community 'ownership' of the unit - and secondly, lack of new and stimulating content. On the other hand, where community ownership, proper system maintenance and relevant content updates are present, the site grows in popularity and becomes effective in terms of ICT literacy and community engagement. This confirms the important role of social resources in the acquisition of access to ICT as stressed by Warschauer (2002).

Due to the extremely remote locations of many sites, proper system maintenance is possible only where the status of the system can be ascertained. This is achieved either by the presence of a community champion who provides feedback to the maintainers, or by the installation of a technical mechanism for automatic site status reporting.

The Future

In the quest for improving the lives of the poorest of the poor, there is no finish line. The DD team will continue to install terminals throughout South Africa. Interest from other countries on the continent and abroad has already resulted in several DDs being installed beyond the boundaries of South Africa, including Lesotho and Ethiopia. As the challenges around installation and maintenance are resolved, an even greater focus will be given to long-term sustainability of each site through various means including sponsorship, advertising

Figure 11. Graph showing the increase and maintaining of effectiveness over time (scenario 2)



revenue, linked service provision (for example income-generating printing services) and other community-inspired initiatives aimed at sustaining equipment life. An installation and maintenance entity - separate from the research side - is currently being set up to handle the repetitive day to day aspects that occur. The issues of suitable Internet provision and user-generated content will be given greater attention, offering users more active participation. More robust clustered DD mesh networks will be created to enable communities to communicate and share information between themselves at no cost to the user. Research will continue to investigate and evaluate the long-term impact of the introduction of DDs into communities, aiming for optimal hardware and software design to serve the ICT learning needs of people in impoverished parts of the world.

CONCLUSION

ICT will continue to play an increasingly important role in the lives of people and in society in general. The development of computer literacy is a necessity, not a luxury, and developing countries are missing out on many of the advantages afforded by ICT, largely due to a lack of computer facilities as well as trained ICT teachers. Unsupervised learning, such as that afforded by the DDs provides a mechanism to promote mass computer literacy in developing countries.

From both a technical and social standpoint, this project has proved to be an interesting challenge. The team learnt a lot about the innovative use of technology in rural South Africa, but even more about the social and cultural aspects that accompany the introduction of ICTs in such communities. We were also encouraged by the quantity of positive feedback received from users of the machines and external observers of the project.

A design-based research approach has been extremely valuable in merging research with actual on-site installations. Through the introduction of equipment into real-world communities, careful observation of the use of this equipment and cyclical refinement and redesign of the equipment, the team has produced an innovative, powerful and popular device that is making a real impact in communities.

The results of open source based multi-terminal DD configuration are very satisfying. Compared to the two sites where single-terminal DDs were installed, the sites with multi-terminal DDs experienced considerably less competition for access. The various participants also had more time to interact with the DD and to consolidate their learning.

The DD initiative is feasible as a means of providing supplementary ICT literacy training, provided there is sufficient funding for both ongoing installations and maintenance of the equipment, as well as community buy-in. Community members themselves have expressed a need for more DDs. Users in underprivileged and rural parts of South Africa can now join the growing digital community. This initiative could truly open a Digital Doorway for people who have not previously had access to computing, enabling them to become computer literate.

Despite the many challenges to be faced in this daunting task of education and poverty alleviation, the excitement of community members, grateful thanks and appreciative smiles of users of Digital Doorways makes the effort worthwhile.

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APPENDIX

Hardware

Figure 12 indicates the various hardware elements contained inside the 3-terminal DD housing (square box) as well as the network elements that make up the entire system.

In addition to the hardware displayed in the diagram, the server is connected to a bluetooth dongle, and the GPRS antenna is housed inside a custom-constructed radome that allows the signal to propagate outwards while the antenna remains protected inside the radome. Each terminal has its own webcam.

As mentioned earlier, it is critical that the maintenance team be informed when a remote system stops functioning. A mechanism for providing update status information of each site has been included in the design. The GPRS modem is employed to transmit a 'sign of life' signal back to a central server which keeps a record of all sites and their current status.

The existence of actual machines in the field served to inform the research side of the project at all stages, providing good synergy between design and research as the project matured.

Specialised Content

What-What Mzansi (quiz game)

This game was developed for the DD to provide content matter specifically relevant to South Africa. The game takes the form of a question and answer session, with correct answers increasing the participant's score. A locally developed musical score and local voice talent ensure that the game is engaging and contextual.

Figure 12. Digital Doorway hardware and network components

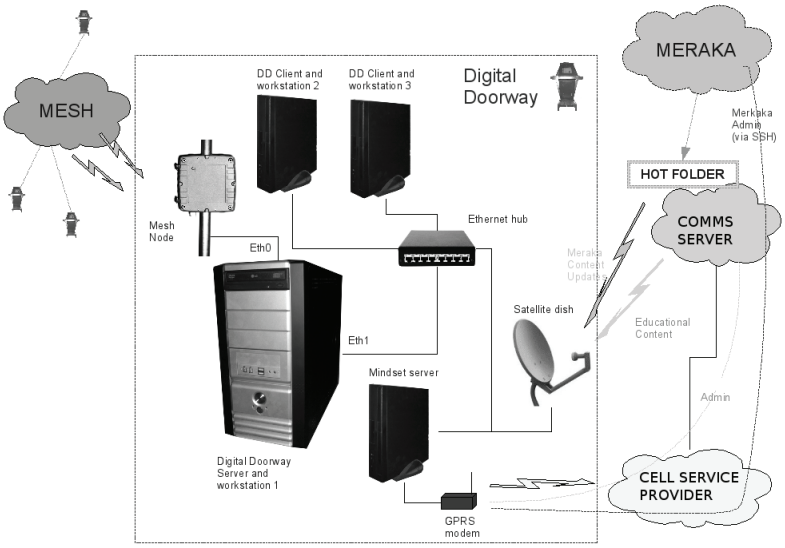
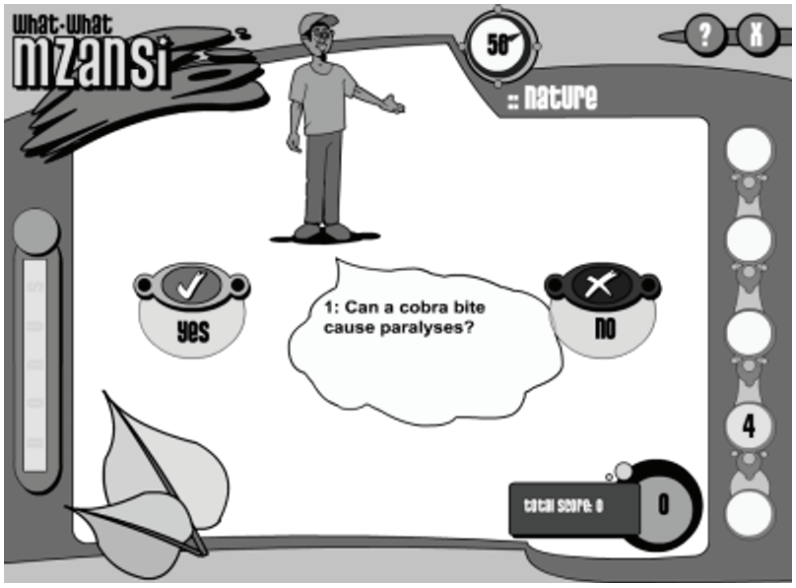


Figure 13. Screen shot of the What-What Mzansi quiz game



Themba's Journey (Life Skills Game)

This game is multi-lingual, custom-designed and implemented to teach basic life skills in the context of a journey from the countryside into the city. It is authentic, situated in the real world, as the main character is faced with choices (e.g. whether or not to take drugs). The user decides on a course of actions, with each action having direct consequences, favourable or unfavourable.

Snapshots of User Activity

The following three snapshots were generated using data received via satellite and illustrate typical user activity at a site.

Snapshot 1:

Location: Multi purpose community center - MPCC
Participant: 12 year old male
Logged in at: Thursday, 17h57
Last recorded activity: 18h46
Analysis period: 49 mins, 17h57 - 18h46
17h57 – 18h00: Webcam application
18h00 – 18h01: Digital Doorway Homepage
18h01 – 18h04: 'Potato Guy' graphical application
18h04 – 18h05: Inkscape vector illustrator
18h05 – 18h06: 'Little Miss Spider' movie
18h06 – 18h08: Electricity document
18h06 – 18h32: Wikipedia (open encyclopedia)

Figure 14. Screen shot of Themba's Journey game

18h32 – 18h40: Science of rollercoasters
18h40 – 18h41: Beginner's guide to electronics
18h41 – 18h45: NASA videos
18h45 – 18h46: Theory of relativity document

It is notable that, although the user tended to application hop, he spent 26 minutes (more than half his time) on Wikipedia, followed by 14 minutes on scientific applications.

Snapshot 2:

Location: Rural High School
Participant: 14 year old male student
Logged in: Saturday, 15h30
Analysis period: 1 hour 20 mins, 15h30 - 16h50
15h30 – 15h50: Mindset (curriculum based educational content)
15h50 – 15h57: File manager navigation
15h57 – 16h22: Mindset (curriculum based educational content)
16h22 – 16h27: 'Little Miss Spider' fun movie
16h27 – 16h41: Webcam application
16h41 – 16h43: 'Sol' game
16h43 – 16h43: 'Gcompris' educational activities
16h43 – 16h44: 'Kmplot' plotting application
16h44 – 16h45: 'Kasteroids' game
16h45 – 16h50: 'Potato Guy' graphical application

This user must have decided to come in on a Saturday to use the computer. The initial 20 minutes were spent on the Mindset educational material initially. Thereafter his activities turned to less serious pursuits.

Snapshot 3:

Location: Public library
Participant: 19 year old female
Logged in at: Thursday, 15h25
Last recorded activity: 17h05
Analysis period: 1 hour 40 mins, 15h25 - 17h05
15h25 – 16h29: Wikipedia (open encyclopedia)
16h29 – 16h30: NASA video clip
16h30 – 16h33: 'Electricity and magnetism' document
16h33 – 16h36: 'Health and Safety – electricity' document
16h36 – 16h40: 'HIV Aids facts' document
16h40 – 16h42: 'Beef – cattle castration' document
16h42 – 16h43: 'Are my pigs healthy' document
16h43 – 16h44: 'Alice in wonderland' story
16h44 – 16h47: Science simulations application
16h47 – 16h48: 'Lowfat cookbook' document
16h48 – 16h51: Wikipedia (open encyclopaedia)
16h51 – 17h05: Science simulations

This user spent the first hour and 5 minutes browsing the on-line encyclopaedia (Wikipedia). It is interesting to note that the science simulation applications were visited briefly at 16h44 (for three minutes) and then again at 16h51 (for thirteen minutes), a good indication that she had become aware of that particular application and actively sought it again at a later stage.