Design research as a framework to evaluate the usability and accessibility of the Digital Doorway

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Abstract

The usability and accessibility of interactive system interfaces, as well as their evaluation constitutes important focus areas of human-computer interaction (HCI). One of the families of evaluation methods that can be used to assess the usability and accessibility of a given interface is the heuristic evaluation method. Heuristic evaluation can be conducted by applying general purpose heuristics or through heuristics that are specifically developed for the given interface. Developing specific heuristics hardly ever involves the use of a sound and recognized research methodology. Design research is increasingly being used as a theoretical and methodological framework for information systems research in general, and HCI research in particular. Design research is a problem-solving approach, involving the creation of artefacts through a rigorous process of design-evaluate-redesign. In a novel approach, we first utilized the design research paradigm in the development of application-specific heuristics, and then also to evaluate the usability and direct accessibility support provided by the Digital Doorway, a non-standard computer system deployed amongst underprivileged communities in South Africa with the aim of promoting computer literacy. This paper discusses the approach we followed.

Keywords

Design research, accessibility, usability, Digital Doorway, heuristic evaluation.

Introduction

The design research paradigm is increasingly being used to provide a theoretical and methodological framework for information systems research in general, and human-computer interaction (HCI) research in particular. HCI is a field of study concerned with the design, implementation and evaluation of interactive systems taking into account the context of use and the task the user needs to accomplish.

According to Archer (1981) design research is a systematic inquiry with the goal of obtaining knowledge of, or knowledge in, the concrete expression (embodiment) of configuration, composition, structure, purpose, value, and meaning in artificial man-made things and systems. Design research is a systematic problem-solving approach, involving the creation of artefacts through a rigorous process of design-evaluate-redesign, with the results of the research efforts communicated to relevant stakeholders (Vaishnavi and Kuechler, 2004).

The usability and accessibility of interactive system interfaces, as well as their evaluation constitutes important focus areas of HCI. Usability is generally defined in terms of an application's effectiveness, efficiency, and user satisfaction in a specified context of use (International Organization for Standardization, 1998). Without appropriate usability, content that could be of potential benefit may not be utilized and users may abandon the system altogether (Barnum, 2002; Nielsen, 2003). Accessibility relates to the design of systems that can be perceived, operated, understood and used by people with varying abilities (Henry, 2007). Usability and accessibility are complementary design concepts that enhance the user experience. In order for an application to be usable, it must be accessible, and vice versa. For example, an interface that provides information through sound alone can not be used by a user with a hearing impairment. Likewise, a design that meets the technical specification for the provision of alternative text for graphic elements on an interface, may not be usable if the alternative text is not meaningful in the context of use (Henry, 2002).

Adherence to design principles and guidelines during the development process is therefore not sufficient to ensure usability and accessibility. Interactive systems should also be evaluated to determine whether users will be able to use any given application to accomplish their goals (Dix et al., 2004). Various usability and accessibility evaluation methods exist. Some of the most established methods are heuristic evaluation, cognitive walkthroughs, surveys, usability testing, and the use of automated software tools (Dix et al., 2004; Greeff and Kotzé, 2009; Harty, 2011; Henry, 2007; Nielsen, 1994; Preece et al., 2007). Several of these methods require expert evaluators whilst others rely on end-user involvement. Accessibility evaluation can be incorporated into usability studies. For example, people with disabilities can be included as participants in user testing while the set of heuristics utilized in a heuristic evaluation can include heuristics that focus on accessibility concerns (Henry, 2007).

The heuristic evaluation method is generally accepted as a relatively easy and cost-effective evaluation method due to its flexibility. The real value of heuristic evaluation lies in the use of suitable heuristics (Jeffries et al., 1991; Preece et al., 2007). While the original set of general heuristics developed by Nielsen (1994) can be utilized for interface usability evaluations, its use may not be appropriate or sufficient for evaluating interface accessibility or to evaluate contemporary interactive systems and *non-standard systems*. To cater for the special characteristics of such systems, *application-specific heuristics* are developed (Berry, 2003; Desurvire et al., 2004; Sim et al., 2009).

Developing specific heuristics hardly ever involves the use of a sound and recognized research methodology. In a novel approach, we first utilized the design research paradigm in the development of application-specific heuristics, and then also to evaluate the usability and direct accessibility support provided by the application. In this case the application was the Digital Doorway (DD) – a walk-up and use *non-standard*[33] computer system deployed amongst underprivileged communities around South Africa with the aim of promoting computer literacy as part of the effort to narrow the digital divide. The system provides a classical example of a non-standard system for which the use of general purpose heuristics is not sufficient to evaluate the usability and accessibility of applications installed (see section 2 for an overview of the DD).

[33] Non-standard in this context means systems that do not display standard operating system interfaces or use standard equipment.

While several sets of application-specific heuristics have been developed for other domains, none of the authors reporting on such developments have used design research (or has explicitly stated the use of the design research approach) to do so. For example, Berry (2003), developed application-specific heuristics through the evaluation-based heuristic derivation method. Using this approach, he developed heuristics for evaluating notification systems by analyzing results from previous evaluation studies and synthesizing the common problems into eight categories of heuristics.

This paper discusses the approach we followed. The primary focus of this paper is on the use of the design research paradigm to derive application-specific heuristics, and to evaluate the usability and direct accessibility support provided in the DD. The paper reports on the heuristics derivation and evaluation process, focussing on the research process – the paper does not present the outcome of performing the actual evaluations of the DD software and interfaces (these are presented in (Adebesin et al., 2010a; Adebesin et al., 2010b)).

Section 2 briefly describes the DD, its components and purpose. In Section 3, we overview different research paradigms, with a special focus on the research paradigm that we have used, namely, design research. Section 4 briefly describes the basic design research process. Section 5 provides a detailed discussion of the design research approach we followed to develop the evaluation instruments for the DD. In Section 6, we reflect on the outcome of the evaluation process and conclude the paper in Section 7.

Overview of the Digital Doorway

The DD project is a joint initiative between the South African Department of Science and Technology (DST) and the Meraka Institute of Council for Scientific and Industrial Research (CSIR). Based on the 'hole in the wall' concept from India (see www.hole-in-the-wall.com/), the project aims to promote computer literacy through unassisted learning (Gush et al., 2010). The systems are installed at venues such as schools, police stations and community centres. Since the commencement of the project, 206 DDs have been installed around the country.

DDs are housed in rugged, custom-designed kiosks with multiple terminals that can be accessed simultaneously by users. A three-terminal DD is shown in Figure 1.Each of the terminals has a metal keyboard with reinforced touchpad for input. The robust housing and metal keyboard help to minimize vandalism (Gush et al., 2010). Pre-loaded software applications and content, in the form of educational games, reference materials (Wikipedia-like pages), Mindset applications, and audio books, run on the Ubuntu Linux operating system. However, the interface does not follow any particular design standard or operating system interface.

DDs are targeted at users with little or no computer literacy living in impoverished communities around South Africa. Although the project aims to provide access to computing technology to children and adults, the majority of DD users are children and young adults (Greyling and Smith, 2008; Gush et al., 2010). Recent data on application usage patterns showed that 77% of registered users are males, with a mere 23% females (Gush and De Villiers, 2010).

Ever since the installation of the first DD in 2002, the DD project has mainly focused on providing physical computer access to underprivileged communities around the country. The systems were deployed without any formal usability evaluation of the software applications installed on them.

Figure 1: A three-terminal Digital Doorway (www.digitaldoorway.org)

Despite the fact that the project has focused on hardware development, the hardware does not currently support the use of assistive devices, such as screen readers for visually impaired users. Furthermore, the environment of use of the DD sometimes imposes additional restrictions on the use of the system (e.g. noise and glaring of the sun). It has thus become essential for us to consider, over and above usability, also the level of direct accessibility support in the evaluation of the DD.

Our research focused on the development of suitable usability and accessibility evaluation methods that can be used to evaluate the existing applications and interfaces of the DD, and to assist in the design of future software applications to be deployed on the DD. This paper focuses on the research process we followed in developing these methods.

Selecting appropriate research paradigm

There are three classic research paradigms, namely the positivist, interpretive and critical (or constructionist) research paradigms. A fourth research paradigm that is becoming prominent in information systems research is design research (Fallman, 2003; Stolterman, 2008; Zimmerman et al., 2007).

A research paradigm relates to the philosophical worldviews that shape the conduct of research (Creswell, 2009; Oates, 2006; Terre Blanche and Durrheim, 2006). Three primary philosophical worldviews are the ontological, epistemological and methodological worldviews. Ontological views refer to the nature or form of the research area to be investigated, epistemological views relate to the relationship between the inquirer (researcher) and what can be known, while methodological views define the ways in which the inquirer can go about obtaining knowledge on the phenomenon of interest (Terre Blanche and Durrheim, 2006). A fourth type of worldview is the axiological view, which relates to 'things the researcher holds in value' and the impact of such values on the conduct of research (Vaishnavi and Kuechler, 2004). Table 1

provides a summary of the ontological, epistemological, methodological and axiological worldviews of the four research paradigms mentioned above.

The following subsections provide a brief overview of the classic research paradigms and the design research paradigm, followed by a motivation for using design research in our study.

Table 1: Philosophical assumptions of the four research paradigms (Adebesin, 2011; Terre Blanche and Durrheim, 2006; Vaishnavi and Kuechler, 2004)

	Philosophical assumptions			
Research paradigms	**Ontology**	**Epistemology**	**Methodology**	**Axiology**
Positivist	- Single, stable reality - Law-like	- Objective - Detached observer	- Experimental - Quantitative - Hypothesis testing	- Truth (objective) - Prediction
Interpretive	- Multiple realities - Socially constructed	- Empathetic - Observer subjectivity	- Interactional - Interpretation - Qualitative	- Contextual understanding
Critical/ Constructionist	- Socially constructed reality - Discourse - Power	- Suspicious - Political - Observer constructing Versions	- Deconstruction - Textual analysis - Discourse analysis	- Inquiry is value-bound - Contextual understanding - Researcher's values affect the study
Design	- Multiple, contextually situated realities	- Knowing through making - Context-based construction	- Developmental - Impact analysis of artefact on composite system	- Control - Creation - Understanding

The positivist research paradigm

The positivist research paradigm, often called 'the scientific method', is based on the assumption that there is an orderly arrangement to the world we live in. It is the de-facto paradigm of choice in natural sciences research, for example, physics, biology and chemistry. Positivist researchers' epistemological belief is that the physical and social reality exist independent of the researcher, and that the object of study possesses characteristics that can be measured objectively (Myers, 1997; Oates, 2006; Vaishnavi and Kuechler, 2004).

Positivist researchers typically employ quantitative research methods, which can take the form of experiments or hypothesis testing (Myers, 1997; Terre Blanche and Durrheim, 2006; Vaishnavi and Kuechler, 2004). Findings from such research can typically be repeated and generalized to the entire population (Olivier, 2004; Oates, 2006).

The interpretive research paradigm

The interpretive research paradigm is based on the assumption that there is no single reality out there and people's knowledge of reality is a construction of their minds. Such construction is constantly in flux, and it is influenced by language, shared meanings and societal norms (Klein and Myers, 1999; Oates, 2006; Terre Blanche and Durrheim, 2006; Vaishnavi and Kuechler, 2004). It is one of the de-facto paradigms of choice in social sciences research.

Ontologically, the interpretive researcher assumes multiple realities, which are socially constructed. In contrast to the positivist, an interpretive researcher is not detached from research participants and the aim is to obtain a rich understanding of the study context rather than make predictions (Oates, 2006; Terre Blanche and Durrheim, 2006; Vaishnavi and Kuechler, 2004). Interpretive studies typically employ qualitative methods such as participant observation, interviews, case studies, and action research (Creswell, 2009; Oates, 2006; Vaishnavi and Kuechler, 2004).

The critical or constructionist research paradigm

The critical research paradigm, like interpretive research, is based on the assumption that reality is socially constructed. However, it goes further, supporting the notion that such construction is influenced by various power relations that exist amongst people, for example, political, cultural and economic power relations. In addition to attempting to understand the prevailing social context, the primary goal of the critical researcher is to emancipate people from injustices (Myers, 1997; Oates, 2006).

As in interpretive studies, critical researchers often utilize qualitative research methods, such as ethnography and case studies, where the researcher goes beyond mere discovery of the culture of a specific group and seeks to uncover centres of power, unstated assumptions and so on, with the aim of empowering the group. Action research is another method that can be employed in critical research, where the ensuing change enables people to challenge those in position of power (Oates, 2006).

The design research paradigm

According to Bayazit (2004) design research is concerned with the expression of man-made things, how these things perform their jobs, and how they work. Design research by definition changes the state of the world through the introduction of man-made artefacts (Vaishnavi and Kuechler, 2004). Hevner et al. (2004:76) described design research as essentially being a "problem-solving paradigm, with the aim of creating innovations. The innovations provide the definition of ideas, practices, technical capabilities, and products, such that the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished". Design research is traditionally employed in engineering fields and what is termed 'science of the artificial' (Hevner et al., 2004).

Ontologically, design researchers assume multiple, contextually-situated world states. The ontological viewpoints shift in design research through the various circumscription cycles. The epistemological assumption of the design researcher is rooted in the concept of 'knowing through making' (Vaishnavi and Kuechler, 2004).

Design research was found to be the most appropriate research paradigm to use in our research.

Why design research?

An immediate question that may arise in the mind of the reader is why we have chosen the design research paradigm over any of the others.

Science may be viewed as the process of designing theories (Walls et al., 1992). While science is concerned primarily with analysis, design is oriented towards synthesis. A scientist becomes a designer when he designs instruments to test theories, and a designer sometimes becomes a scientist if he applies scientific theories in implementing his designs. The purpose of a theory is prediction or explanation of a phenomenon. Natural science theories, as used by positivists, pertain to the physical or biological world and explain relationships in the natural world or predict the behaviour of aspects of that world. Social science theories, as used by the interpretivists and critical realists, perform the same function for the behaviour of people either individually or in groups.

The primary difference between the natural and social science theories and design theories lies in how they deal with purposeful behaviour or goals (Walls et al., 1992). Goals have no meaning in natural science as such. The only goals that exist in this domain are those by the theorists who are constructing the theories. Social science theories may deal with goals as the objects of study, but the purpose of the theory is to explain why specific goals exists or to predict the outcomes associated with goals; it is not to achieve those goals.

The purpose of a design theory is to support the achievement of goals and must deal with goals as contingencies (Walls et al., 1992). It can never involve pure explanation or prediction, but is rather prescriptive. Design theories are composite theories encompassing theories from the natural, social and mathematical sciences, and show how explanatory, predictive or normative theories can be put to practical use.

In the research reported on in this paper, we had a goal, namely to derive application-specific heuristics, and to evaluate the usability and direct accessibility support provided in the DD. It therefore closely fits the fundamentals of design theory and therefore design (science) research.

Design research is a set of analytical techniques and perspectives complementing the positivistic (natural) and interpretivistic (social) perspectives on information systems research (Vaishnavi and Kuechler, 2004) and supporting design theory. It involves the analysis of the use and performance of designed artefacts in order to comprehend, explain and often improve the behaviour of aspects of information systems. In the process of doing so, it may involve methods typically used by the positivist or interpretivist paradigms. We also need to clarify the issue of action research compared to design research. Action research (often employed in interpretive or critical research) aims to contribute to both the practical concerns of people in a specific situation and to the goals of social science through joint collaboration within the boundaries of a mutually acceptable ethical framework (Rapoport, 1970). The definition assumes a concrete client, making it highly context dependent. Some researchers incorrectly tend to equate it with design research. When compared with action research, an essential difference is that design research assumes neither any specific client nor joint collaboration between the researcher and the client. The developed artefact typically aims at addressing a specific class of problems (or class of artefacts) (Walls et al., 1992) in a way that is useful in addressing specific problems of a specific client, in our case the DD and the Meraka development team. More fundamentally, design research is a research orientation (paradigm), while action research is a research method (that may be employed in design research, for example in evaluating the artefact).

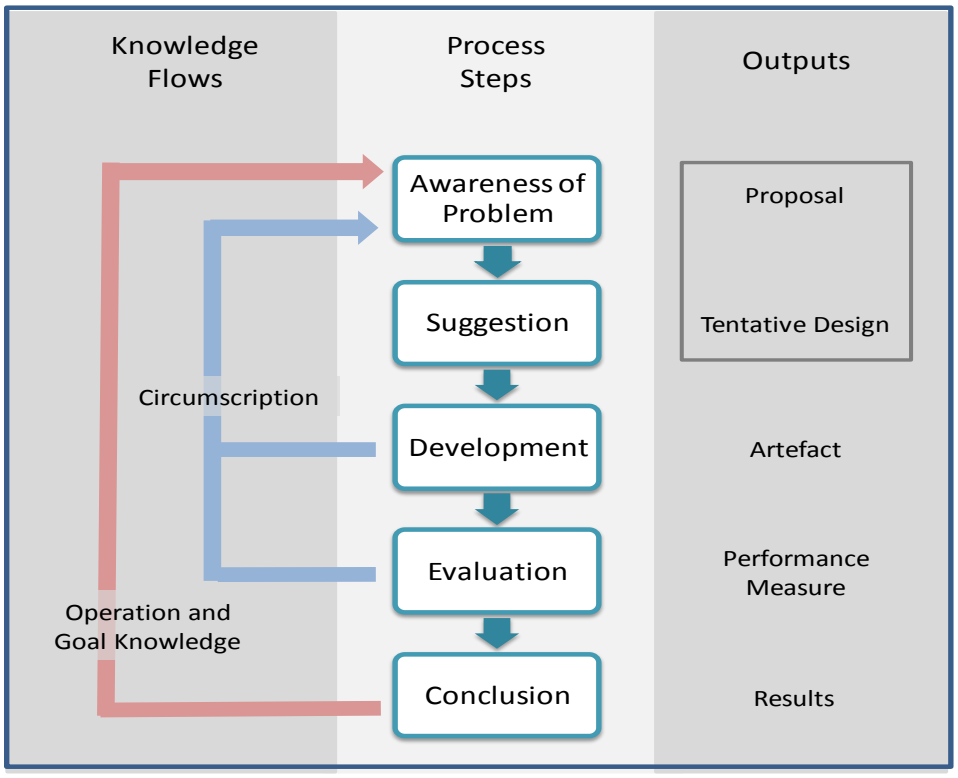


Figure 2: Phases of design research (Vaishnavi and Kuechler, 2004)

The design research process

The word 'design' represents both a verb and a noun, in other words, both a process and a product (Walls et al., 1992). Thus design research must have two aspects: one that deals with the process of design and one that deals with the product of design (the artefact).

Design research generally consists of iterations through five phases (Vaishnavi and Kuechler, 2004), as illustrated in Figure 2:

1. *Awareness of problem:* This is the phase where the design researcher becomes aware of the problem. This may emanate from multiple sources, such as, academia or industry. The end product of this phase is a proposal for new research.
2. *Suggestion:* The suggestion phase, which is closely linked to the awareness phase, is a creative phase wherein the design researcher envisions new functionality. The new functionality may be based on new or existing components. This phase results in tentative design, for example a prototype.
3. *Development:* This is the phase where the artefact, which is based on the tentative design, is created. The implementation technique utilized will vary, depending on the artefact being created. It is not compulsory for the implementation to be novel, since uniqueness lies in the design and not the creation of the artefact.
4. *Evaluation:* This is the phase where the developed artefact is assessed, using quantitative and qualitative methods to tentatively explain any deviation from expectations. Embedded in the evaluation phase is an analytic sub-phase, where the design researcher hypothesises on the behaviour of the artefact. The evaluation results, together with lessons learnt from the development phase feed back into the next iteration, which starts at the second phase. These cycles of

suggestions, development and evaluation continues until the end product is assessed as 'good enough'.

5. *Conclusion:* This is the final phase of the current research effort, which culminates in the development of a satisficing artefact, or the production of an artefact whose behaviour is judged as 'good enough', although not necessarily optimal. In the conclusion phase, researchers compile reports and group lessons learnt into those that add to the body of knowledge and those that may lead up to further research.

New knowledge production is indicated by the arrows labelled *Operation and Goal Knowledge* and *Circumscription. Circumscription* is particularly important in design research since it generates the understanding that can only be gained by the act of construction, and is based on the logic that assumes every fragment of knowledge is valid only in certain situations (Vaishnavi and Kuechler, 2004). The researcher learns when things do not work according to theory, due to misunderstanding, incompleteness, etc. The interruption of the design process and forcing it back to the awareness phase constitutes valuable constraint-knowledge that contributes to the understanding of incomplete knowledge that informed the original design.

The product of design research in the context of information systems include: constructs (the conceptual vocabulary of a problem or solution domain), models (set of propositions or statements articulating the relationships among constructs), methods (set of steps to perform a task), instantiations (operationalization of constructs, models and methods in an environment) (March and Smith, 1995), and better theories (Rossi and Sein, 2003).

The process of evaluating the Digital Doorway

Our research followed the design research process articulated by Vaishnavi and Kuechler (2004), and described in section 4. It involved two nested cycles of the design research phases. The goal of the first (outer) cycle was to determine appropriate evaluation methods to evaluate the usability and accessibility of the DD, while the goal of the second (inner) cycle was to develop the specific heuristics for evaluating the DD. The following two subsections discusses these two cycles, respectively.

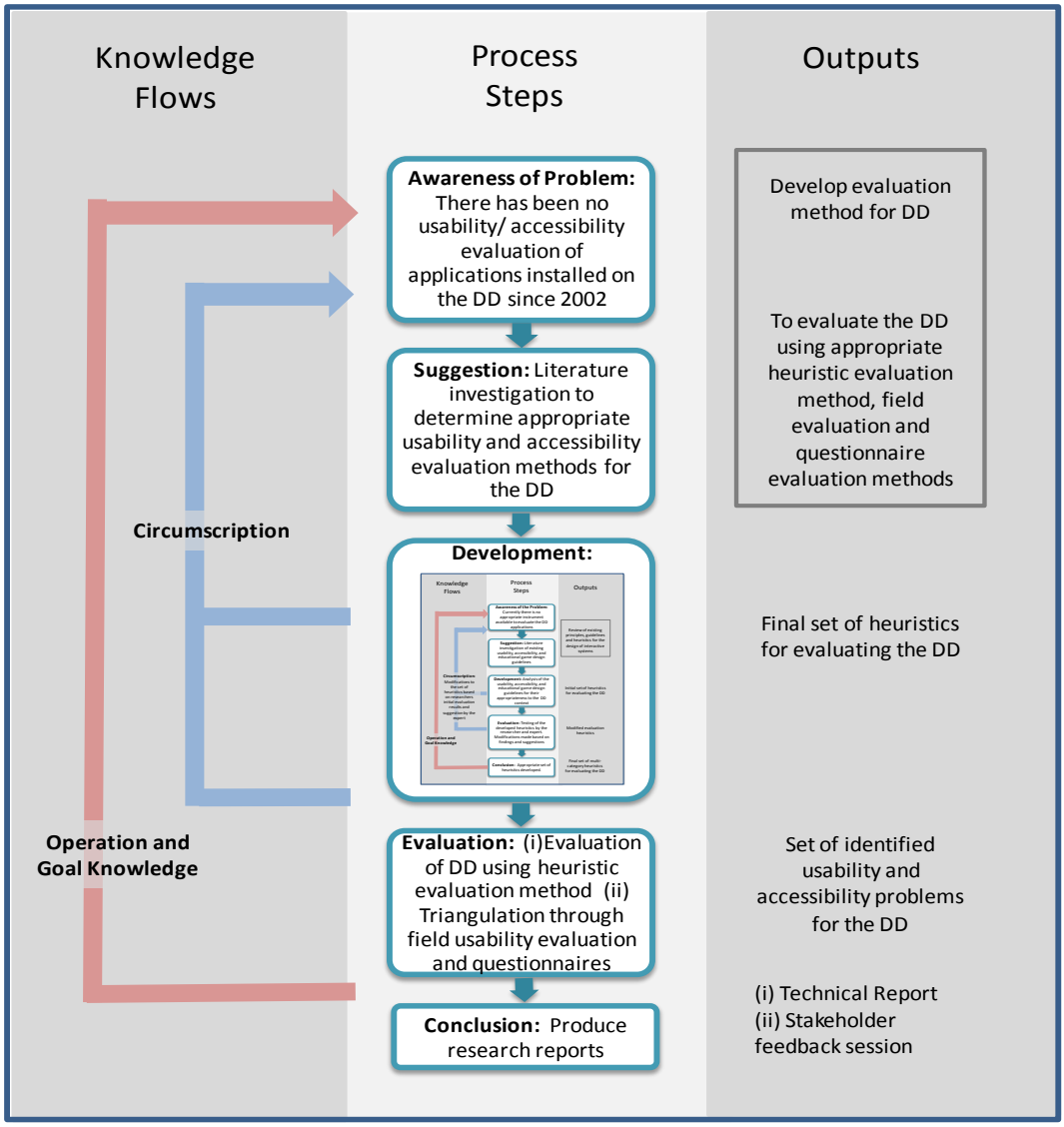
Designing appropriate evaluation methods for the DD

The application of the five phases of design research during the first cycle to design appropriate usability and accessibility evaluation methods for the DD, as illustrated in Figure 3, involved:

1. *Awareness of problem:* The first DD was installed at the rural community of Cwili in the Eastern Cape Province in 2002. Until our research, the DD project has primarily focused on providing physical computer access. The systems are deployed without conducting any usability evaluation or applicability tests on the software installed on the system. Given the important role that usability and accessibility has to play in the effort to narrow the digital divide (bridges.org, n.d; Nielsen, 2006; Wilson, 2006), this phase led to the realization of the need to evaluate the usability and direct accessibility support provided by the DD to determine whether the target user groups are able to use the system to perform real tasks.
2. *Suggestion phase:* This phase investigated the applicability of the standard usability and accessibility evaluation methods for evaluating a selection of interfaces and applications installed on the DD, in order to determine the appropriate evaluation method(s) for the DD. Our choice of evaluation method(s) was influenced by the physical and logistical constraints imposed by the DD, the importance of involving real users and availability of requisite resources.

   Although we had access to a state-of-the-art usability testing laboratory, practical considerations meant that we could not use controlled usability testing method since it was not feasible to

physically move the DD to the usability laboratory. Furthermore, observation and logging software in the usability laboratory is only compatible with the Windows operating system while the applications on the DD run on the Ubuntu Linux operating system. Also, the DD does not support the use of assistive devices, which makes the inclusion of users with disabilities impossible. Thus, we selected the heuristic evaluation method as the primary evaluation method. Application-specific heuristics were required for the purpose and had to be developed. To complement the heuristic evaluation, we chose, as triangulation instruments during the evaluation phase, to conduct field evaluation through direct observations and questionnaires at a local school where the context of DD usage is retained.



3. *Development:* This phase represents the development of application-specific heuristics for evaluating the interfaces and applications installed on the DD. The phase triggered the second, inner cycle of design research, discussed in section 5.2. A selection of the heuristics to be used by the expert evaluators were used to form the basis of the semi-structured questionnaires to be used during the field evaluation.

4. *Evaluation:* This phase represents the formal evaluation of the DD through the involvement of expert evaluators and real users. Using the heuristic evaluation method, a team of five usability and/or accessibility experts evaluated a selection of interfaces and applications on the DD (Adebesin et al., 2010a). To complement the heuristic evaluation, nine learners participated in a field evaluation where we observed their interaction with applications on the DD as they completed pre-defined tasks (Adebesin et al., 2010b). A post-evaluation questionnaire was also completed by participants.
5. *Conclusion:* This is the final phase of the research where findings from the study was compiled and communicated to high-level managers and the DD project team members. Detail of the findings from the evaluation can be obtained from (Adebesin et al., 2010a; Adebesin et al., 2010b).

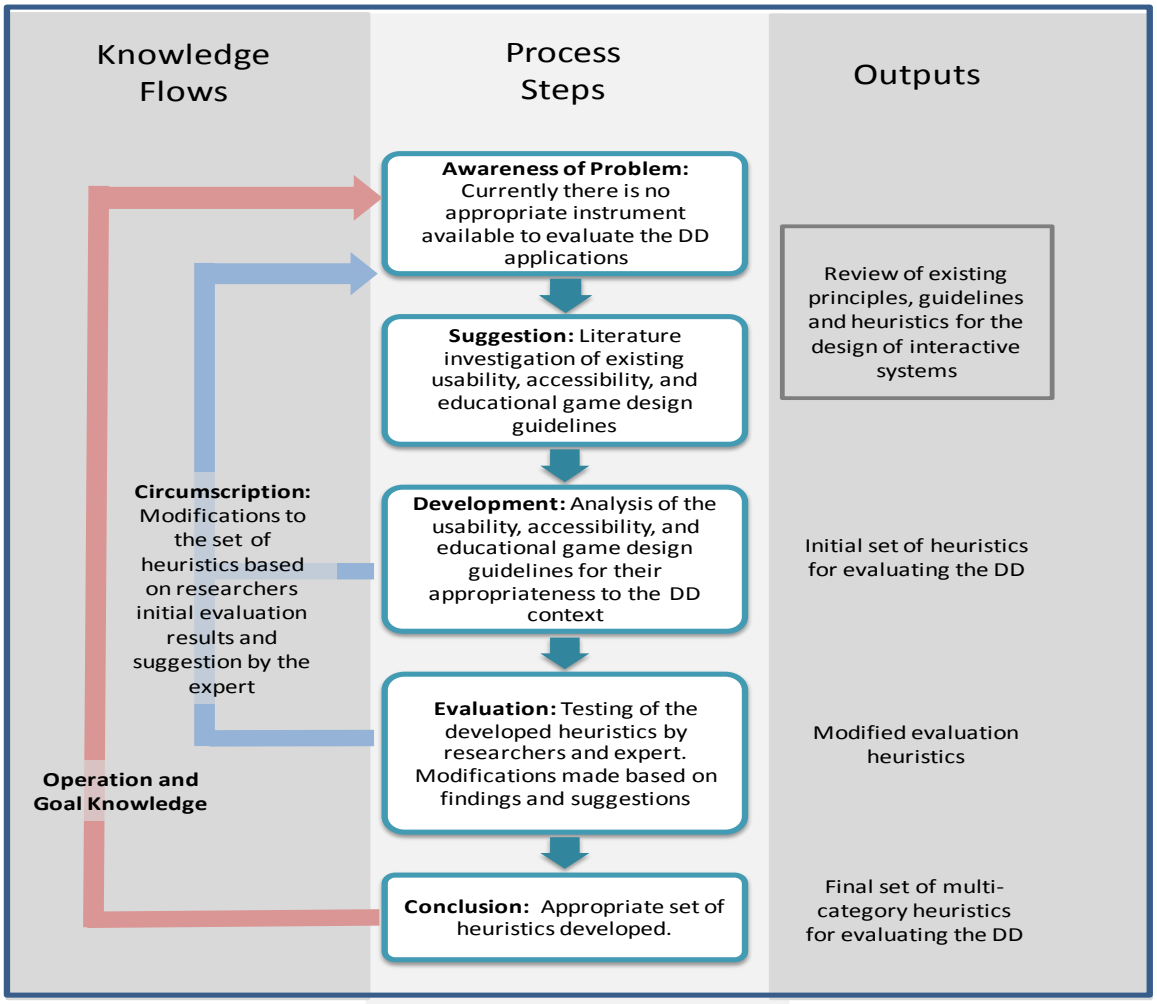
Designing application-specific heuristics for the DD

This cycle was triggered during the development phase of the outer cycle. It involved the development of application specific heuristics for the DD. The application of the five phases of design research to design appropriate application-specific heuristics for the DD, as illustrated in Figure 4, involved:

1. *Awareness of problem:* The suggestion phase of the outer design research cycle identified the heuristic evaluation method as being suitable for evaluating the usability and direct accessibility support provided in the DD. However, the value of the heuristic evaluation method is dependent on the use of appropriate heuristics. General-purpose heuristics, such as those by Nielsen (1994), are inadequate for assessing accessibility. Neither are they suitable for evaluating the special usability requirements of educational games. Hence, it was essential to develop an integrated set of heuristics focusing on the characteristics of the interfaces and applications evaluated.
2. *Suggestion:* This phase involved an extensive literature investigation of existing principles and guidelines for the design of usable and accessible interactive systems. In addition, guidelines for the design of computer-based educational game applications were also reviewed.
3. *Development:* This phase represents the development of the multi-category evaluation heuristics for evaluating the DD. The heuristic set focused on general usability, form interface design guidelines, direct accessibility, and educational game usability. We reviewed the principles of usable interface design proposed by Dix et al. (2004), Gelderblom's (2008) guidelines for the design of children' technology, Mayhew's guidelines for the design of form-fill interfaces (1992), Nielsen's heuristics (1994), the usability principles by Preece et al. (2007), the design principles by Norman (2001), and Shneiderman's (1998) golden rules for interface design, for their appropriateness in evaluating the interfaces and applications installed on the DD.

   To cater for direct accessibility issues, we looked at the seven principles of universal design (Story et al., 1998), the web content accessibility guidelines 1.0 (1999), Section 508 of the United State (2000), and IBM software accessibility checklists (2009). Because the applications evaluated are also educational games, we reviewed guidelines that relate specifically to such applications. Game-specific guidelines studied are those proposed by Alessi and Trollip (2001), Desurvire, Caplan and Toth (2004), Malone (1980, 1981), and Shelley (2001).

Figure 4: Inner cycle of the design research process – designing appropriate application-specific heuristics for the DD



To determine the applicability or otherwise of the principles and guidelines to DD context, we examined each of the principles and guidelines taking into account the interfaces and applications to be evaluated, the types of users the DD is aimed at, and the typical environment of DD usage. For example, we found the principle of multithreading (as proposed by Dix et al. (2004)) was not pertinent to the usability of the DD since the system only supports the execution of one task at a time.

We grouped the heuristics into four categories, namely: general usability, form usability, direct accessibility, and educational game usability heuristics respectively.

4. *Evaluation:* This is the phase where we evaluated the developed heuristics for their level of coverage of the DD environment. An initial evaluation was done by the first author, where she conducted a heuristic evaluation of a selection of interfaces and applications on the DD. Problems identified were matched to the heuristics. The heuristics were modified to provide for problems that could not be matched to any heuristic.

   Following the initial evaluation and modifications to the heuristics, an expert with usability and accessibility experience conducted another round of heuristic evaluation on the selected interfaces and applications with the aim of assessing the completeness and terminology usage in the heuristic set. Further modifications were made to the heuristics based on findings and suggestions from this expert.

   The output of this phase was the set of multi-category heuristics which were used by independent expert evaluators during a formal heuristic evaluation of the DD. Due to page restrictions, we could not provide the complete set of heuristics derived (the set is available in (Adebesin, 2011)).
5. *Conclusion:* This phase marks the end of the inner cycle of the design research process. Following the process of design-evaluate-redesign, the set of heuristics were judged as being adequate for evaluating the selection of interfaces and applications installed on the DD. Thus the evaluation phase of the outer cycle was resumed.

Discussion

The output (artefact) of our research was a tool to evaluate the application and interfaces of the DD. The activities carried out to develop the tool mapped well with the phases of the design research approach, which typically involves an iterative process of design-evaluate-redesign. Using the design research paradigm, we were able to generate a rich set of evaluation heuristics over three iterations (circumscription). In addition, the fact that an evaluation phase is explicitly built into the design research process ensured that the emerging heuristics were assessed for their appropriateness to DD the context.

Scientific research in general is characterised by the principles of abstraction, originality, justification and publication, to distinguish itself from solutions developed in the practitioner community (i.e. user organizations) or by commercial providers (i.e. software vendors, consulting companies). To be scientific, each artefact in information systems research must be applicable to a class of problems (abstraction), contribute to the advancement of knowledge (originality), be justified in a comprehensible manner and must allow for its validation (justification), and yield a benefit for the respective stakeholder groups (benefit). Design-oriented IS research is normative in the sense that the development of the artefacts is guided by the desire to yield a specific benefit and to satisfy certain objectives (Österle et al., 2010).

Employing the design research paradigm and the design research process proposed by Vaishnavi and Kuechler (2004), we were able to meet all the principles for scientific research and specifically scientific research in the realm of information systems:

- Abstraction: The class of problems is the evaluation of non-standard interactive computer systems such as the DD.
- Originality: The set of application specific heuristics developed is completely novel. The use of heuristics to evaluate interactive systems is generally considered to be straightforward, flexible and cost-effective, especially when the target system is a standard application. However, the challenge

is in the selection of appropriate evaluation heuristics when the application in question is non-standard, as is the case with the DD.

- Justification: Justification and validation took place continuously using a variety of methods, including expert reviews, field studies and questionnaires.
- Benefit: The resulting evaluation heuristics would not only benefit the developers of software and interfaces for the DD, but also the wider community of users at which the use of DD is aimed.

The choice of research paradigm must also be considered – would one of the other paradigms not have sufficed? Some remarks can be made in addition to our discussion in section 3.5. The study was a typical qualitative research study. It therefore did not fit a typical positivistic research approach involving quantitative methods. While some aspects of the study may fit a typical interpretive research paradigm, involving qualitative data gathering methods such as a directed literature review and analysis of existing usability evaluation methods, the interpretive research paradigm did not adequately represent the iterative activities that were required for our study, and neither the goal-directed nature of our research. The latter is particularly unique in the design research approach.

Conclusion

In this paper, we presented the process to establish the appropriate usability and accessibility methods for the evaluation a selection of interfaces and applications installed on the DD, as well as the derivation of a set of multi-category heuristics suitable for assessing the usability and direct accessibility support provided in the DD, using the design research paradigm.

We described how two cycles of design research phases were utilized to guide the decision on appropriate evaluation methods, the generation of application-specific heuristics (following the selection of heuristic evaluation as the primary evaluation method), and the process we followed to ensure that we produce a heuristic set that provide adequate coverage for the interfaces and applications that were evaluated.

Design research proved to be an appropriate research paradigm to follow when embarking on the development of suitable usability and accessibility evaluation methods in the HCI domain.

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