Supporting rural teachers 21st century skills development through mobile technology use: A case in Cofimvaba, Eastern Cape, South Africa

Adele Botha
CSIR Meraka/ UNISA
Pretoria, South Africa
abotha@csir.co.za

Marlien Herselman
CSIR Meraka/ UNISA
Pretoria, South Africa
mherselman@CSIR.co.za

Abstract— The purpose of this paper is to provide a general overview of an initiative known as ICT for rural education development (ICT4RED), as part of the larger TECH4RED. With a specific focus on the research and teacher proffesional development components. The ICT4RED initiative is supporting rural teachers to integrate tablets in teaching mathematics and science in schools in Cofimvaba in the Nciba district of the Eastern Cape in South Africa. The teachers have to "learn to earn" the technology and have to apply the use thereof in their classrooms with evidence of this use. This is operationalised through 10 proffesional development sessions over a period of 6 to 9 months. This paper will focus mainly on the teacher professional development as well as research components attached to this initiative..

Keywords— Mobile technology use, tablets, design science methodology, lessons learnt

I. INTRODUCTION

The TECH4RED is a joint initiative between Department of Science and Technology (DST), the Department of Basic Education (DBE), the Department of Rural Development and the Eastern Cape Department of Education (ECDoE), focused on the Nciba Circuit of the Cofimvaba School District in the Eastern Cape Province.

The collaborating partners recognise the continuing responsibility and obligation of the Province, District and Circuit to improve the quality of learning and teaching. The initiative will work to strengthen that capacity and thus the likelihood of a sustained improvement in the education outcomes.

To assist in addressing the challenge of quality education in rural areas, the DST has identified a need for a large-scale initiative to assess the possible impact of a holistic deployment of multiple innovations and technologies in the improvement of rural educational outcomes. The role of the DST is to infuse innovative ideas and technologies into the initiative, and to support the identified interventions at school level. The DST has commissioned the CSIR to support this project and to implement specific objectives. Meraka Institute thus decided to create an integrated large scale demonstration environment in the Cofimvaba school district in the Eastern Cape that will serve as a test-bed for technologies to support the education system. This holistic, systems-based approach will include a focus on technologies and domains such as:

- ICT
- Health and Nutrition
- Transport and Logistics
- Building technologies
- Water & Sanitation
- Renewable energy
- ICT for Rural Education Development

This paper will mainly focus on the Research and Teacher Professional Development concerns within the ICT for Rural Education Development (ICT4RED) aspect of the initiative.

This initiative will take place at schools in the Nciba Circuit of the Cofimvaba School District. The learning will enable recommendations towards scaling solutions to other areas in the district and possibly for national implementation.

The ICT4RED initiative endeavours to investigate the implications of providing access to digital content to rural South African schools by utilising advanced mobile devices such as tablets, e-readers and smartphones by using the 25 Nciba Circuit schools as a test bed. Approximately 6500 learners will be targeted at these schools. The project will test various models, in terms of devices, content, infrastructure, connectivity, integration into the school environment, costs, sustainability, logistics, support and maintenance, operational support and teacher-training.

CSIR Meraka will take overall project management responsibility for the ICT4RED initiative and will incubate an operational management environment for the duration of the project. Once the research has been completed, the learning will be shared and disseminated, a model (or models) will be developed which will enable wider-scale rollout and it is envisaged that relevant policy will follow. The Nciba Circuit will need to be handed over as part of the wider implementation.

II. AIMS AND OBJECTIVES

The key objective of this (ICT4RED) project is to create a platform to enable widespread participation and collaboration between multiple stakeholders (private, public, academic, civil society, community) to implement a large Technology for Education Demonstrator in the Cofimvaba rural school district

that has the buy-in of key stakeholders and has demonstrable impact on education and quality of life in the region

The Cofimvaba initiative aims to immediately apply new and existing technologies in a replicable and sustainable way for evaluation and possible adoption and implementation across the rural education system

The objectives of the initiative are as follows:

- Design systemic and sustainable approaches to providing access to digital content by learners at poor and marginalized rural schools in South Africa;
- Design, develop, test and improve new and evolving educational technologies, devices, platforms and processes that support the access to digital content for rural school environments;
- Measure the effect of this project on the 21st century skills of learners; and
- Use the evidence from the research within this context to inform policy in an integrated and coherent manner.

III. APPROACH

The education system is a particularly complex and sensitive one, with many seemingly unrelated factors able to affect it. Any intervention should be as all-encompassing as possible, taking into account all the dimensions of the project. The project acknowledged that important to note that the technology component is only 10% of a so-called "technology intervention" and often success and failure is determined by the softer issues, such as training, making provision for cultural factors and the appropriate engagement processes within rural communities. In addition, although the focus is on ICT, there are many other dependencies that can affect the outcome of these types of interventions, both directly and indirectly.

It is critical to identify all the components of the project that need to be covered and to ensure that a multidisciplinary team is put in place in order to scope, plan and manage these components. The eTextbook initiative on its own cannot be seen as the panacea to a dramatic improvement in learning outcomes - it is one intervention amongst many that is needed. In order to develop this framework the project will adopt the Design Science methodology approach

IV. METHODOLOGY

Design science research, focuses on creation and the purpose of design is "to change existing situations into preferred ones" [1]. Design science addresses 'wicked problems' in IS [2] and is fundamentally a problem-solving paradigm. Wicked problems as explained by Hevner & Chatterjee [3] relate to the ill-defined environmental contexts, creativity and teamwork to produce effective solutions.

Design science research creates artefacts which is something created by humans usually for a practical purpose and March and Smith [4] differentiate among four different types of artefacts: concepts, models, methods and instantiations. Two important characteristics of design science artefacts are relevance and novelty [5]. First, an artefact must solve an important problem: i.e., being relevant. Second, to

differentiate design science research from routine design, Hevner et al. [6] suggest that design science research should address either an unsolved problem in a unique and innovative way or a solved problem in a more effective or efficient way. Furthermore, Baskerville, Pries-Heje and Venable [7], Carlsson [8], McKay and Marshall [9] are of the view that DS research in IS should be underpinned by a socio-technical perspective. To this end, Carlsson et al [8] suggest a socio-technical approach to DS research in IS. This socio-technical approach points to the reciprocal relationship between the two disciplines namely the engineering-inclined DS and socially-inclined natural sciences. Furthermore, Donner et al [10] consider ICT4D as a multidisciplinary domain that facilitates collaboration between engineers and social scientists to develop innovative solutions to challenges faced by communities in resource-constrained environments. This too supports the view on need for both the engineering-inclined DS and social science research activities. In recognition of this, and also because of the socio-technical nature of ICT4D domain, this study has developed a set of socio-technical requirements which the proposed solutions must satisfy.

Design science research contribution requires the following processes [11-13]:

- Preliminary study/analysis of practical problems and needs,
- development of solutions/prototype phase,
- evaluation and testing and
- assessment or reflection

Hevner et al. [6] were the first authors to provide an Information systems framework to show where design science research fits. This framework was later improved by Pirenen [14] as well as Wang & Wang [13]. The figure below is adapted from Hevner et al. [6] and Pirenen [14] and indicates the relevance and rigour of design science research in Information systems and is also used as the theoretical framework for this paper.
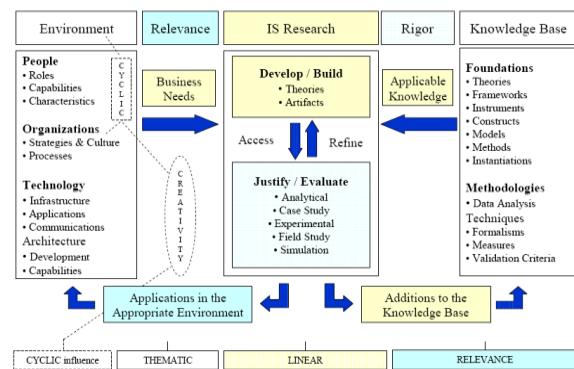

Fig. 1. Information System Framework [6, 14]

Figure 2 borrows the IS research framework found in Hevner et al. [6] and overlays a focus on three inherent research cycles: relevance, rigour and design with creativity and how each of these contributes to the knowledge base of foundations and methodologies. In this framework people, organization and technology are three components of the

environment of design research. Business needs are the drive force for design research so that design research can be relevant. Design research must add knowledge to the knowledge base so that it can be rigorous. Hevner et al. [6] also proposed seven guidelines for design research: design as an artifact, problem relevance, design evaluation, research contributions, research rigour, design as a search process and communication of research [15].
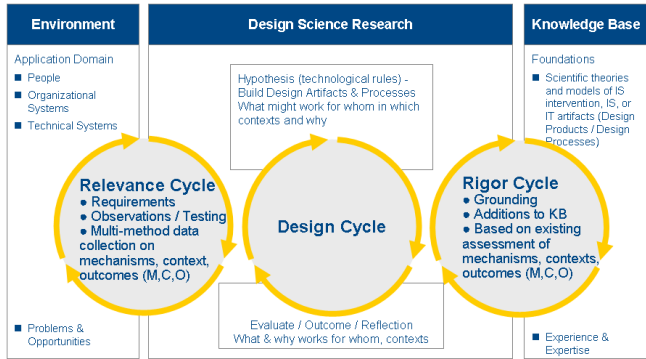

Fig. 2.   IS Design Science Research Cycles [8, 16]

A. Relevance Cycle

The *Relevance Cycle* initiates design science research with an application context that not only provides the requirements for the research (e.g., the opportunity/problem to be addressed) as inputs but also defines acceptance criteria for the ultimate evaluation of the research results. The output from the design science research must be returned into the environment for study and evaluation in the application domain [16].

This study has identified a potential research opportunity as the lack of framework or model for development of 21st century school environments which support access to digital content in rural areas of South Africa. A list of requirements as outlined in the relevance cycle will be developed for the resource constrained context as contextualized by the literature study of relevant case studies and position papers. The requirements will be reviewed by experts for validation to ensure the design is built on a solid foundation. The requirements will provide input for the *Design Cycle* and will be used to evaluate the developed design artefacts and collect data on the mechanisms, context, and outcomes.

B. Rigor Cycle

The *Rigor Cycle* provides existing knowledge to the research project to ensure its innovation. It is contingent on the researchers to thoroughly research and reference the knowledge base in order to guarantee that the designs produced are research contributions and not routine designs based upon the application of well-known processes [16]. Additions to the knowledge base as results of design science research will include any extensions to the original theories and methods made during the research, the new meta-artefacts (design products and processes), and all experiences gained from performing the research and field testing the artefact in the

application environment [6, 16]. For the knowledge base this study will use

- scientific theories, methods, and meta-artefacts found through literature review;
- the researcher's expertise and experience; and
- the 12 component inputs of the model in figure 4 below

in the areas of mobile technology access and use for 21st century school environments.

C. Design Cycle

The internal *Design Cycle* of research activities iterates more rapidly than the *Relevance* and *Rigor Cycles* between the development of technological rules, the construction of an artefact, its evaluation, and subsequent feedback to refine the design further [6, 8]. Simon [1] describes the nature of this cycle as generating design alternatives and evaluating the alternatives against requirements until a satisfactory design is achieved. In this study, the design cycle involves the development and evaluation of a framework or model.

D. Design Science Research Guidelines

This project will follow the seven guidelines to perform design science research in Information Systems discipline described by Hevner, March [17].

TABLE I.   DESIGN-SCIENCE RESEARCH GUIDELINES [6]

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods
Guideline 4: Research Contribution	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences

E. Design Science Research Process (DSRP)

Peffers et al. [18] developed a conceptual process and mental model for carrying out design science research and presenting it. The proposed Design Science Research Process (DSRP) is consistent with prior literature and includes six steps [6, 12, 19]: problem identification and motivation, objectives for a solution, design and development, evaluation, and communication (Figure 3 and 4). The iterative nature of the Design Science Research Process is represented by the arrows between the six steps. The Design Science Research Process

introduced by Peffers et al. [18] will be adapted for the design of the model or framework for this project as depicted in Figure 4 below:
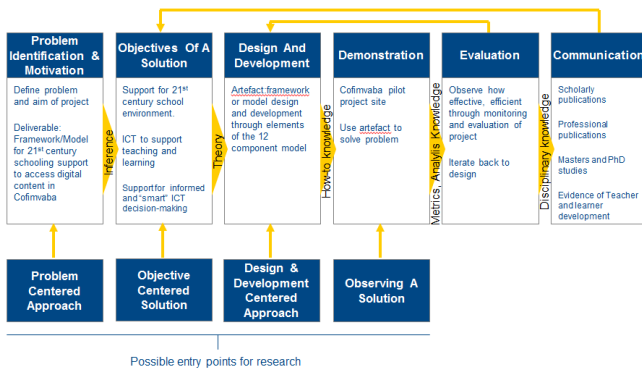

Fig. 3. Design Science Research Process for this project adapted from (Peffers et al, 2007)

F. Components of the project

The framework which will be developed to address the purpose of this project will address specific components which are indicated below in the building blocks. The 12 components each represent a specific focus with a champion to drive it and to be involved in reporting. Figure 5 identifies the various components and activities of the eTextbook initiative.
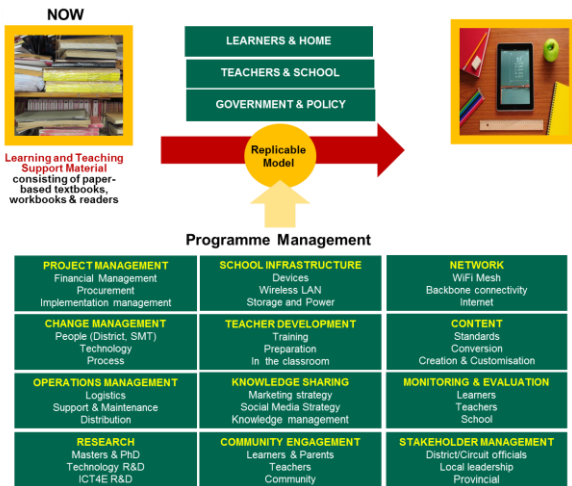

Fig. 4. Component Model for ICT interventions in Schools [20]

This paper aims to report only on the Research and Teacher Professional Development concerns within the ICT for Rural Education Development (ICT4RED) aspect of the initiative

1) Phase 1

The schools that will be targeted in PHASE 1 were selected in collaboration with the Cofimvaba School District officials and consist of the following:

- 3 x Senior Secondary – Arthur Mfebe, Siyabalala and Kwahza
- 6 x Junior - St Marks, Bangilizwe, Mvuzo, Gando, Mtimbini, Zamuxolo

Different models will be tested at each school with regard to:

- School preparation
- Devices
- Content management processes
- Support and maintenance
- Device management

The process of implimentation will be as follows:

a) STEP 0: Meeting with principals and deputies, School Governing Bodies and District Officials

- Explanation and buy-in

b) STEP 1A: Workshop with principals and deputies, and allocated ICT champion

- Hand out tablets to each attendee
- Preparatory course − change management and how to manage technology in a school
- Homework to be completed before STEP 2

c) STEP 1B: Workshop with District Officials

- Hand out tablets to each attendee
- Course on how to support tablet rollouts in schools

d) STEP 2: Teacher Professional Development

- Tablet per teacher
- Model as per Arthur Mfebe – "Learn to Earn"
- Homework to be completed over 4 courses (until the researchers are sure that they are ready), then STEP 3

e) STEP 3: MobiKits to Schools

- According to size of school
- Shared tablets in the classroom
- MobiHub installed (local wifi in the classroom, local content)
- Monitoring & evaluation as to usage and management of these devices
- Continuing training of the teachers (who continue to do their "homework")
- Once happy that the school is ready, STEP 4

f) STEP 4: Tablets to learners

- Continuing training of the teachers (who continue to do their "homework")
- Wifi installed in school plus linked to other schools in cluster
- MobiCharge and other charging options installed
- Tech support person appointed
- Pedagogy support person appointed
- Ops Management and support

g) STEP 5: Expansion to other schools (in district – PHASE 2)

- Go to STEP 0

In parallel with the rollout, an intensive activity will be undertaken to provide curriculum-approved content, focusing on literacy, numeracy (Foundation Phase) and Mathematics

and Science (Grades 4 to 12). Content and applications will be sourced for English as a first additional language for all grades.

The pilot will run in parallel with existing paper textbook and content models; it does not currently intend to replace the status quo. The intent is to phase in mobile devices to support teaching and learning inside and outside the classroom as part of a blended learning environment, where various modes of teaching and learning material co-exist comfortably.

CSIR Meraka will take overall project management responsibility for the initiative and will incubate an operational management environment for the duration of the project. The learning will be shared with government and a model (or models) will be developed which will enable wider-scale rollout. The Nciba Circuit will need to be handed over as part of the wider implementation.

V. PRELIMINARY RESULTS ON TEACHER PROFESSIONAL DEVELOPMENT

Currently the project is in Phase 1, having completed a successful pilot at Arthur Mfebe senior secondary school where the teachers have completed and graduated from the initial 10-Course Professional Development Programme designed to support teachers in the use of Mobile Technology to facilitate learning in the classroom. In addition, the learners have all received a tablet, a local Wifi network was installed, a content server (i.e. MobiServer) was installed together with charging & safe storage station (i.e. MobiCharge). Further, an implementation of a maths and science teaching systems combined with learner resource material that was developed at the NMMU Govan Mbeki Mathematics Unit is operational.

This initial pilot formed the basis for expansion to an additional 12 schools in Phase 1, where the headmasters and teachers have already received Tablets and completed 4 modules of the revised Professional Development Programme.

The "learn-to-earn" model has proved to be a promising concept at Arthur Mfebe Senior Secondary School. Based on this a micro skill accreditation programme was instituted through gamification principals as badges.

The Continuous Professional Development course was successfully designed around the teacher as an autonomous agent with the power to significantly influence the appropriate integration of technology in teaching. Training took place in small, focused 3 hour sessions, 2pm – 5pm, every 3 weeks. These were conducted over a period of 10 training sessions after school hours and attendance was communicated as compulsory. The expectation was that teachers would implement what they had learnt after every module. Currently the majority of teachers are able to actively use their tablets while most also bought attractive covers.

Teachers have demonstrated that they are able to integrating the strategies and technology affordances demonstrated in the training in and out of their classrooms and two of the teachers have been chosen to facilitate the professional development of the next phase. One of the teachers at the school has enrolled to do her Master's in Education and 4 of the teachers have become active participant on twitter (One of the teachers won the newbie twitter award at a local conference).

VI. PRELIMINARY RESULTS ON THE RESEARCH COMPONENT

This research component will aim to:

- Supervise and/or support selected postgraduate students at universities in the Education, Information systems, IT/Computer Science departments to do their studies based on the project purpose, scope and objectives.
- After a year (escalating as the years of study increase) have some postgraduate research results and literature which can be applied by other components and champions of this project and for dissemination of results at national and international forums;
- Sharing findings in peer reviewed publications (Market the project to wider community);
- Ensure that all research on this project is tracked and monitored for completeness and quality purposes;
- Summarise all results to add value to the project in the end;
- Provide a methodological framework of all research done on this project;
- Add value to Human Capital development of both students and other researchers involved in the project (including teachers at Cofimvaba);

A. Desired outcomes

Based on the aims/objectives above the following are desired outcomes to add value to the overall framework/model development from a research perspective and develop a methodological framework of research conducted at Cofimvaba. Also to keep a track record of all published research papers and results on this project and compile evidence of students completing their degrees and adding value to the Human Capital Development component of this country. Work on published peer reviewed papers with teachers of Cofimvaba as possible co-creators/authors with students and have research results at postgraduate level which can be used for reporting and for Monitoring and Evaluation purposes and to add value to other components of this project. The research component also envisage to develop greater awareness of the value of the project to replicate the final model in other provinces or areas and add value to the development of teachers in Cofimvaba based on their involvement in research with students and other researchers from the Higher Education Institutions.

B. Current status of the research component

Currently there are 12 students who are involved from University of Fort Hare (Information Systems department in East London), NMMU (Department of Computer Science) and University of Pretoria (Education Faculty) and University of Johannesburg (Education department).

C. Title for dissertations and theses

Postgraduate students will **not** be provided with a title but have to read the project proposal and then based on their

interests and previous degree knowledge, decide on a title which will fit into the scope of the study. Two PhD students and 10 Masters students ranging from Education, Information Systems and Computer Science students are involved from the above universities.

D. Process that was followed:

- Universities and specific departments/Faculties are approached to determine if any of their students will be interested to be part of the project at postgraduate level. They did the selection themselves and Meraka researchers were requested to provide overview of the project and also some ideas on what are the possibilities.
- Students have to provide a summarised overview of their possible title, scope, and provide a one pager which answer: What, where, when, how and why as a starting point within 2 weeks for further discussions.
- Individual in-depth discussions are held with interested students and their supervisors at the universities. (one supervisor from Meraka and one at the specific university is a requirement).
- Students have 2-6 months (depending on the university) to complete a proposal which has to be accepted by their respective research committees.
- Students have to get their own ethical approval at their universities which will be used to strengthen the ethical approval for this project at the CSIR.
- A MoA is completed with each university and its respective Faculties and departments with timelines and specific deliverables;
- Each proposal accepted from the universities will have to be supplied to this agenda and team of this project;
- Regular progress reports have to be completed (one every term) per annum for each student;
- Supervisor and co-supervisor meet with students every quarter to trace progress and address queries;
- All students and co-supervisors are taken to Cofimvaba to meet the teachers before they do field work;
- Field work trips are arranged to coincide with other interventions at the schools in Cofimvaba;
- Scholarship are awarded to students based on their progress;

It is essential to collaborate with other 11 components (figure 4) of this project for research purposes. Also to understand how the research can add value to these components within the scope of the project. Especially with pedagogy, change management, network and stakeholder engagement, knowledge sharing as well as Monitoring and Evaluation.

VII. CONCLUSIONS

From the progress to date on this project it is evident that a lot has been invested in the teachers and learners as well as at universities to collaborate and to all add value to the development of a framework or model which can be replicated in other areas of other provinces in South Africa. The correct

approach and methodology also support the progress. This project provide an overview of how mobile learning can be applied to support teachers and learners through the use of technology where they are supported but also allowed to play around and develop their own initiatives to successful use and development of their competence and skills. This project is evidence of how important components can play a collective role to ensure that future initiatives of providing technology to schools will be more successful. The need for how to use the mobile technology and the model of "learn to earn" are ways to ensure use and uptake in schools to promote 21st century skills development, which is needed in our country.

REFERENCES

[1.] Simon, H., *The Sciences of the Artificial*1996, Cambridge, Mass: MIT Press.

[2.] Rittel, H.J. and M.M. Webber, (),. In: , (ed).: , *Planning problems are wicked problems*, in *Developments of Design Methodology*, N. Cross, Editor 1984, John Wiley & Sons: New York.

[3.] Hevner, A. and S. Chatterjee, *Design Science Research in Information Systems: Theory and Practice.*2010, New York: Springer.

[4.] March, S. and G. Smith, *Design and Natural Science Research on Information Technology.* Decision Support Systems, 1995. **15**: p. 251 - 266.

[5.] Geerts, G., *A Design Science Research Methodology and its Application to Accounting Information Systems Research.* International Journal of Accounting Information Systems, 2011.

[6.] Hevner, A., et al., *Design science in information systems research.* Manage Information Systems Quarterly (MIS), 2004. **28**(1): p. 75-105.

[7.] Pries-Heje, J., R. Baskerville, and J. Venable. *Soft Design Science Research: Extending the Boundaries of Evaluation in Design Science Research.* in *2nd International Conference on Design Science Research in IT (DESRIST)*. 2007.

[8.] Carlsson, S., *Design Science Research in Information Systems: A Critical Realist Approach*, in *Design Research in Information Systems*2010, Springer US. p. 209-233.

[9.] McKay, J. and P. Marshall, *Foundation of Design Science in Information Systems. ,* in *Sparks working paper: RISO (Research into Information Systems in Organisations)*2008, Faculty of Information and Communication Technologies, Swinburne University of Technology: Melbourne, Australia.

[10.] Donner, J., *Research Approaches to Mobile Use in the Developing World: A Review of the Literature.* The Information Society, 2008. **24**(3): p. 140 - 159.

[11.] Reeves, P., *How to write Policies and Guidelines: Guidance for Staff*, 2006.

[12.] March, S. and V. Storey, *Design Science in the Information Systems Discipline: An introduction to the special issue on design science research.* MIS Quarterly, 2008. **32**(4): p. 725-730.

[13.] Wang, S. and H. Wang, *Towards innovative design research information systems.* Journal of Computer Information Systems, 2010. **Fall 2010**.

[14.] Pirenen, R. *Research Framework of Integrative Action.* in *Fifteenth Americas Conference on Information Systems.* 2009. San Francisco, California, August 6th-9th.

[15.] Wang, F. and T.C. Reeves, *Why Do Teachers Need to Use Technology in Their Classrooms? Issues, Problems, and Solutions.* Computers in the Schools, 2004. **20**(4): p. 49.

[16.] Hevner, A., *A Three Cycle View of Design Science Research.* Scandinavian Journal of Information Systems, 2007. **19:**(2).

[17.] Hevner, A.R., et al., *Design Science in Information Systems Research.* MIS Quarterly, 2004. **28**(1).

[18.] Peffers, K., et al., *A design science research methodology for information systems research.* Journal of Management Information Systems, 2007. **24**(3): p. 45 - 77.

[19.] Hashim, L., H. Hasan, and S. Sinnapan, *Australian Online Newspapers: A Website Content Analysis Approach to Measuring Interactivity*, in *18th Australasian Conference on Information Systems* 2007: Toowoomba.

[20.] Ford, M., *ICT4RED*, 2012, CSIR Meraka: Pretoria.