ESTABLISHING A HEALTH INFORMATICS RESEARCH LABORATORY IN SOUTH AFRICA

Deshendran Moodley*	Department of Computer Science, University of Cape Town	deshen@cs.uct.ac.za
Anban W Pillay	School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Westville, South Africa	pillayw4@ukzan.ac.za
*Christopher J Seebregts	School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Westville, South Africa	chris.seebregts@jembi.org

*Corresponding author

ABSTRACT

Aim/Purpose	The aim of this project was to explore models for stimulating health informatics innovation and capacity development in South Africa.
Background	There is generally a critical lack of health informatics innovation and capacity in South Africa and sub-Saharan Africa. This is despite the wide anticipation that digital health systems will play a fundamental role in strengthening health systems and improving service delivery
Methodology	We established a program over four years to train Masters and Doctoral students and conducted research projects across a wide range of biomedical and health informatics technologies at a leading South African university. We also developed a Health Architecture Laboratory Innovation and Development Ecosystem (HeAL-IDE) designed to be a long-lasting and potentially reproducible output of the project.
Contribution	We were able to demonstrate a successful model for building innovation and capacity in a sustainable way. Key outputs included: (i) a successful partnership model; (ii) a sustainable HeAL-IDE; (iii) research papers; (iv) a world-class software product and several demonstrators; and (iv) highly trained staff.
Findings	Our main findings are that: (i) it is possible to create a local ecosystem for innovation and capacity building that creates value for the partners (a university and a private non-profit company); (ii) the ecosystem is able to create valuable outputs that would be much less likely to have been developed singly by each partner, and; (iii) the ecosystem could serve as a powerful model for adoption in other settings.
Recommendations for Practitioners	Non-profit companies and non-governmental organizations implementing health information systems in South Africa and other low resource settings have an opportunity to partner with local universities for purposes of internal capacity development and assisting with the research, reflection and innovation aspects of their projects and programmes.

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Recommendation for Researchers	Applied health informatics researchers working in low resource settings could productively partner with local implementing organizations in order to gain a better understanding of the challenges and requirements at field sites and to accelerate the testing and deployment of health information technology solutions.
Impact on Society	This research demonstrates a model that can deliver valuable software products for public health.
Future Research	It would be useful to implement the model in other settings and research whether the model is more generally useful
Keywords	Health Informatics, Capacity Development, Living Laboratory, ICT4D

INTRODUCTION

Health information systems are one of the key pillars of a public health system (1). Developing countries in sub-Saharan Africa have unique environments in which limited infrastructure, lack of specialized technical skills and constrained financial resources impact on the development of national health information systems (NHIS) (2) (3). Consolidating currently fragmented health information systems in these countries into a coherent national information system will increase operational efficiencies, improve decision-making and lead to better health outcomes (4). However, engineering a coherent, effective and sustainable socio-technical enterprise information system of the scale and complexity of a national health information system (NHIS) poses unique and complex challenges in low and middle income countries (LMICs) (5) (6) (7) (8).

Specialized computer science skills are required to analyze and provide long term approaches for system design that cater for interoperability between the dynamic components in a continuously changing NHIS (9) (6) (10) (11). A systematic approach to high-level information system design at national level will also assist African Ministries of Health to better utilize resources available for independent projects implemented by donors, non-governmental organizations (NGOs) and universities (8). Many existing health information system components implemented in African countries are developed by foreign organizations using international donor funds and foreign software developers. Building local technical capacity and a sustainable system for rapid innovation in Africa is crucial to making full use of these investments.

The Health Architecture Laboratory (HeAL) was established and operated between 2011 and 2015 in the discipline of Computer Science in the School of Mathematics, Statistics and Computer Science (SMSCS) at the University of KwaZulu-Natal (UKZN) in Westville, South Africa. The aim of the HeAL project was to establish an advanced computing research laboratory in Africa, to develop African capacity and create a system of innovation and relevant technologies for an African environment.

The specific objectives of the HeAL were to: (i) establish an innovation ecosystem structure for rapid research, innovation and technology transfer; (ii) develop capacity in local implementation organizations by offering specialized Computer Science postgraduate degrees in health informatics to senior technical personnel; and (iii) conduct research in relevant technologies required for coherent, effective and sustainable national health information systems in sub-Saharan Africa. This paper summarizes and reflects on the major activities, experiences and outcomes of the HeAL.

METHODOLOGY

In order to achieve the above objectives, the following initial activities were undertaken:

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- Developed a research agenda to guide and focus the activities of the HEAL and formulate selection criteria for research projects.
- Created a capacity development plan for recruiting and training highly skilled graduates and researchers in this area, which also informed the research agenda and *vice versa*.
- Developed a governance structure for the HeAL, including selection criteria, roles and guiding principles for the Student Selection Committee and the Scientific Steering Committee (SSC)).
- Evaluated (formative and summative) the operation and processes of the HeAL.
- Evaluated (formative and summative) the research and training of the HEAL
- Translated and transferred knowledge produced by the HeAL to appropriate communities.
- Established an outreach and collaboration strategy.

These activities served to guide the operation of the Laboratory in the first two years of operation. We adopted an action research approach to the development of the HeAL. Periods of development were followed by periods of reflection, in partnership with the Steering Committee, and thereafter incorporated into changes to the structure and functioning of the Laboratory.

An external evaluation of the HeAL was conducted by two independent South African academics. The evaluation team conducted site visits at both the HeAL at UKZN and its implementing partner, Jembi Health Systems. Faculty and staff participated in in-depth interviews and the team accessed various documents of the HeAL. The purpose of the evaluation was to determine the extent to which HeAL had met its grant objectives and then to consider: a) the impact of HeAL on its immediate institutional context; b) the impact of HeAL in a wider academic context; c) the contribution HeAL made to the development of participating students; and d) the benefit derived by partnering organizations participating in HeAL.

HEAL INNOVATION AND DEVELOPMENT ECOSYSTEM (IDE)

In order to realise its cross-cutting objectives, the Laboratory needed to establish strategic partnerships with implementing organisations and other research and academic institutions. A strategy and structure was required to effectively coordinate and leverage expertise from each partner. The Laboratory developed the HeAL Innovation and Development Ecosystem (IDE) model to manage the structural and functional evolution of the HeAL during its period of operation.

The final ecosystem model (Figure 1) describes the flow of innovation from the field environment (implementing partners) to the HeAL applied research environment where the ideas and requirements are researched and developed into specifications that, in turn, are productionized back into the field environment. The HeAL consolidated and formalised in Year One its partnership with Jembi Health Systems NPC (www.jembi.org) as a 'living lab'. At the time of the establishment of the partnership, Jembi was a newly formed innovation company spun out of the Biomedical Research Division at the South African Medical Research Council. Jembi's offices were based in Cape Town while, at that time, the HeAL was based in Durban, roughly 1650 km apart. The first two MSc students were employed as senior developers at Jembi, and were offered scholarships to buy out a portion of their time to work on their MSc projects. One of the students was based in the physical laboratory at UKZN and the other remained at the Jembi offices in Cape Town. Their HeAL MSc research revolved around Jembi's implementation projects in South Africa and Rwanda.

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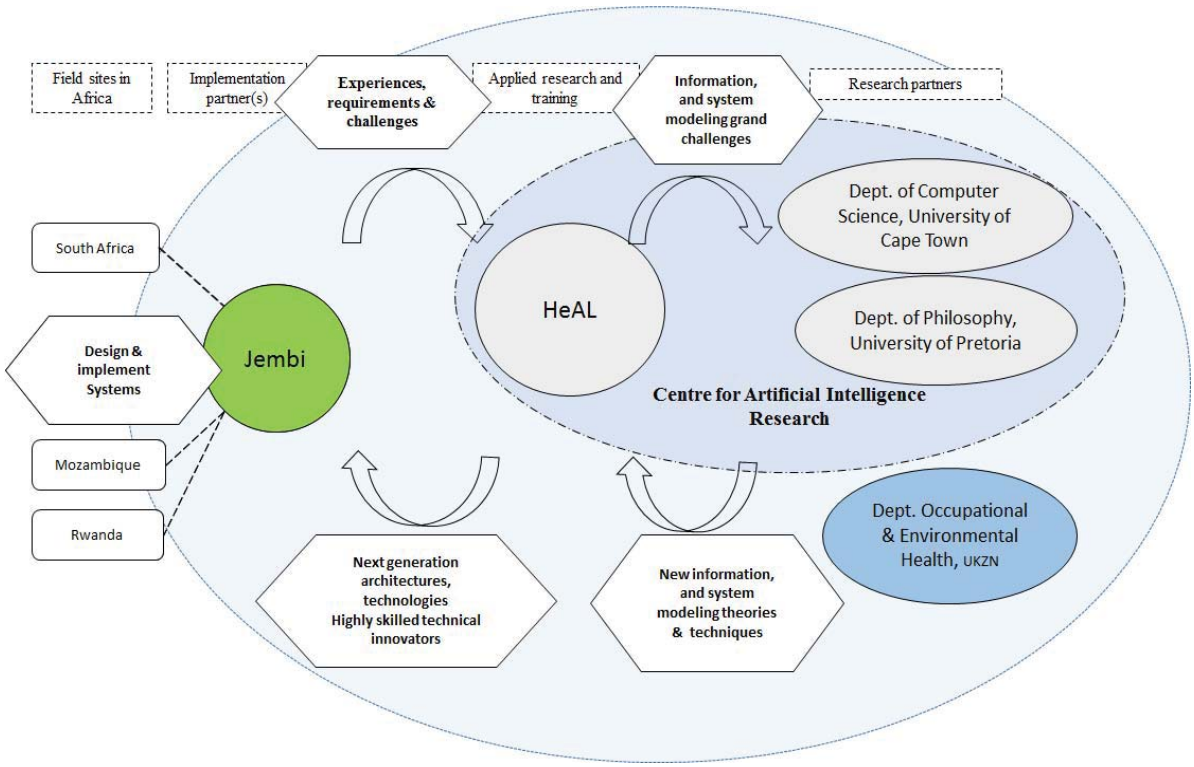

Figure 1. Version 3 of the Ecosystem Model

The Principal Investigator of the HeAL, a fulltime academic at UKZN, was appointed as a non-executive board member of Jembi, while the Founder and CEO of Jembi was appointed as an Honorary Associate Professor at the SMSCS at UKZN. The latest configuration, version 3, of the HeAL capacity and innovation ecosystem showing active research and development partnerships at the end of the project is shown in Figure 1.

HeAL is now situated within the Centre for Artificial Intelligence Research (CAIR), which has been expanded to a national research Centre in Artificial Intelligence and Computer Science, with research nodes at UKZN, University of Pretoria, North West University, Stellenbosch University and University of Cape Town. Through CAIR, collaborations have been initiated with the Department of Philosophy at the University of Pretoria and the Primary Health Care Directorate at the University of Cape Town.

EVALUATION OF THE INNOVATION MODEL

Research outputs

The HeAL's research was eventually consolidated into three research themes, namely:

- Innovation models for health information technologies in sub-Saharan Africa;
- Architectures for national health information systems; and
- Ontology based systems for knowledge capture and decision making.

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Research theme 1: Innovation models for health information technologies in sub-Saharan Africa

The main output of this theme was the refinement and evaluation of the HeAL innovation ecosystem model. Innovation in health information systems engineering requires the collaboration of multiple partners that include research-led institutions such as universities and research organizations, stakeholder communities, open development communities and software development houses. The Laboratory sought to develop and refine a model that would involve these various communities, institutions and organizations and manage the sometimes conflicting interests and concerns.

An initial model was proposed in Moodley et al. (2012) (6). The efficacy of the model was demonstrated in the Laboratory's work in the development of the Open Health Information Mediator (OpenHIM; www.openhim.org) (12). The OpenHIM technology has had impact far beyond expectations and has seen several successful deployments and has spawned an international open-source community. Its success is in large part due to the application of the innovation model. Several other technologies were also developed to different levels of maturity.

Research theme 2: Architectures for national health information systems

Recently, several sub-Saharan African countries have begun the process of developing national health information systems. The architecture suitable for such large, complex systems, especially in low resource settings are still not well understood. Two MSc projects involved an investigation of architectures for NHIS; while the one project investigated high level approaches to NHIS development (8), the second project was focussed on the development and evaluation of a health information mediator for health information exchanges (12).

The first work characterized different approaches that countries could adopt to guide the development of their respective NHIS and evaluated the applicability of these approaches in LMICs before making recommendations that could guide Ministries of Health (12).

The latter project developed and evaluated the OpenHIM), a central component of the Health Information Exchanges. These exchanges have emerged as critical components of modern scalable and sustainable NHIS. This work resulted in the OpenHIM that has seen wide deployment and interest from a large international community (13) (14).

Research theme 3: Ontology based systems for knowledge capture and decision making

Since inception, HeAL has placed strong emphasis on applying the latest thinking and technologies emanating from computer science in the study of health information systems. In particular, it seeks the collaboration of researchers involved in knowledge representation and reasoning and ontology engineering. The development of formal conceptual models is important to deal with semantic inter-operability, access to knowledge and information about human health and understanding of complex adaptive systems, such as national health information systems. These models have potential to deepen an understanding of complex systems, improve the development of tools that support modelling and analysis of HIS and provide rigor in the engineering of such systems.

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Innovation and technology development

A significant component of HeAL activities were related to the identification of technology gaps and the development of relevant technologies. Technology gaps were informed by:

- Current problems and projects at implementation partners
- Availability of students and access to field sites
- Skills and strengths of faculty

The following five technologies were initiated as technology demonstrators, one of which (the OpenHIM) has been developed further into a viable software product, in close association with Jembi:

1. OpenHIM: a central component of Health Information Exchanges that has seen multiple production deployments - Jembi.
2. A prediction tool for HIV antiretroviral drug resistance from clinical data: A completed research prototype was produced and contributed to the community - Jembi and the Africa Centre for Health and Population Studies.
3. An ontology and knowledge-based repository for structuring TB treatment adherence knowledge: A research prototype has been produced - HeAL in-house project.
4. An eHealth regulation ontology: A research prototype has been developed - Jembi and HeAL in-house project.
5. A framework for selecting and adopting an appropriate NHIS architectural approach in a sub-Saharan Africa country - HeAL in-house project.

The Open Health Information Mediator

OpenHIM is an open source software application that was initially developed as an MSc project in the HeAL. The OpenHIM was developed in partnership with Jembi to satisfy a requirement to strengthen interoperability between maternal health applications in Rwanda. A timeline showing the development of the OpenHIM is shown in Figure 2, below.

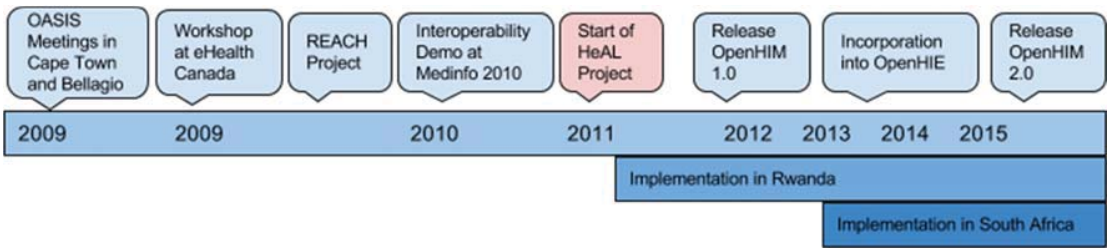

Figure 2 Timeline of the OpenHIM

The first version of the OpenHIM was implemented in the Rwamagana district of Rwanda where it is used to connect and collate information sent by SMS (Short Message Service) by community health workers to an antenatal care facilities using the Open Medical Record System (OpenMRS).

The OpenHIM was modelled on similar software developed in Canada (15). The OpenHIM was successfully deployed in Rwanda for maternal care. Following its early success, the OpenHIM has evolved into a very significant application that is currently being implemented widely as a health information exchange in South Africa at national and subnational level, as well as in other countries. The OpenHIM is also a core infrastructural component of the OpenHIE project that grew out of the Rwanda project. This is a very significant achievement

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for a software component built in a university environment as open source software in such a short space of time and demonstrates the usefulness of the partnership between academia and private sector organisations. The OpenHIM is hosted as an open source software.

During 2014, the OpenHIM was refactored to make it more flexible and version 2 was released at the ICT4H conference in September 2014.

DISCUSSION

The innovation model demonstrated value to all partners. The main finding of the external independent evaluation was that: “HeAL not only contributed academic research, but also positively impacted the wider Health Information Systems space in South Africa by contributing models, tools and technologies that are useful for other organizations developing eHealth applications. HeAL also contributed towards the development of students through scholarships for postgraduate studies as well as supervision and teaching at Honours level.”

The HeAL innovation model provides a strategy for applying advanced theoretical and foundational computer science expertise to the health domain. We expect this to impact on projects designed to better understand health systems as complex adaptive systems and the effect of interventions on the effectiveness and equity of health service delivery

The Laboratory was highly successful with regards to the training of graduates at its main implementation partner, Jembi. The Laboratory has already trained three MSc and one PhD student in Computer Science.

The HeAL has also developed and continue to maintain a strong partnership with Jembi. HeAL played an essential role in building and strengthening Jembi, which is now recognized locally and internationally as a leader in interoperable Health Information Technologies (HIT) in Africa.

HeAL developed an effective ecosystem and platform, the HeAL Capacity and Innovation Ecosystem, for coordinating research, innovation and transfer of health information technologies in sub-Saharan Africa. The Laboratory experienced several challenges during the course of its operation, which provided opportunities for significant learning. Despite these challenges, the Laboratory successfully adapted and established the ecosystem and, via its strong partnerships, has had a substantial influence on health information technology policy in Rwanda, Mozambique and South Africa, The Laboratory also plays an important role in the international OpenHIE community. An external evaluation was also conducted on the HeAL project, which documents and reports the Laboratory’s influence at different levels.

LESSONS LEARNT, RECOMMENDATIONS AND FUTURE WORK

The HeAL project was highly successful in meeting its overall aim and major objectives.
It successfully established an applied Computer Science research Laboratory at the University of KwaZulu-Natal. The lab is now embedded in the Centre for Artificial Intelligence Research which ensures its sustainability and exposes it to new partners and elevates its potential influence and impact in South Africa. It successfully introduced and evolved an innovation ecosystem which harnesses and coordinates the strengths of academic, research and implementation partners to create a sustainable system for rapid innovation for health information technologies in Africa. Its key technology output, the OpenHIM, is deployed at multiple sites in Rwanda and South Africa and is recognized as one of the foremost solutions for interoperability for health information exchange in Africa. In terms of capacity development

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it graduated two highly specialised and talented postgraduate students who are playing leadership roles in the health information space.

Jembi grew substantially during the Laboratory's operation and is now recognised as a leading technology organisation in interoperability solutions for health information technology in Africa. The Laboratory played an important role in Jembi's growth and development.

In terms of the research question: "Can an applied Computer Science research lab in a sub-Saharan African university facilitate and enable local capacity development and sustainable innovation of relevant health information technologies?", our findings show that despite several challenges this is not only possible but important for a sustainable system of innovation for HITs in Africa. A key output of the Laboratory, the HeAL innovation ecosystem, has already been used to deliver and deploy an integral technology solution for interoperability.

Despite some challenges, the results from HeAL indicate that the innovation model is a powerful and resilient approach for harmonizing different research and development efforts around global health IT problems and an implementation-driven approach that tightly binds the work to real needs.

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BIOGRAPHY

PROF DESHENDRAN MOODLEY is currently serving as an Associate Professor at the University of Cape Town. His research interests revolves around developing large scale intelligent architectures, specifically to investigate how ontologies, belief networks and software agents can be used in such architectures. Prof Moodley's qualifications include a PhD and an MSc in Computer Science, both of which were obtained from the University of KwaZulu-Natal.

MR ANBAN W PILLAY is a lecturer at the University of Kwa-Zula Natal. His research interests include knowledge representation and reasoning and agent-oriented software engineering. Mr Pillay is a holder of an MSc degree from the University of Kwa-Zulu Natal.
Position:

PROF CHRIS SEEBREGTS is the founder and the current Chief Executive Officer and eHealth Director of Jembi Health Systems NPC. Jembi is a non-profit company specializing in digital health, headquartered in South Africa, with country offices in Mozambique and Rwanda. Chris is also an honorary associate professor in the School of Mathematics, Statistics and Computer Science at the University of KwaZulu-Natal. Prof Seebregts has a PhD in Chemical Pathology from the University of Cape Town and postgraduate degrees in Computer science and Software Engineering from the University of South Africa. He has worked in the public and private sectors in biomedical and informatics research, information technology management and software development. He is part of the OpenMRS leadership and is recognized internationally as an expert in eHealth. Prof Seegbregts has a vision for improved global health through the development of effective and efficient health information systems, growing partnerships and building local capacity in developing countries.

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TECHNOLOGY DIFFUSION IN A RURAL UNIVERSITY IN SOUTHERN AFRICA

Farivar Rahimi* University of Limpopo, South Africa Farivar.Rahimi@ul.ac.za

*Corresponding author

ABSTRACT

Aim/Purpose	This case study examined the state of development and diffusion of the use of technology in a rural university in southern Africa.
Background	It has been demonstrated that while the levels of interest, utilization and motivation for the use of technology in the teaching practices of the academic community might be regarded as relatively high, there is evidence of a need for improvement, from both a pedagogical perspective and in the way educational technology is used to deliver course content. This case study also highlights opportunities for further improvement in some areas related to ICT services, where these services were being offered, such as in computer laboratories.
Methodology	Two surveys were used to assess the input from staff (109) and students (750).
Contribution	This study has identified the challenges and opportunities that might exist when promoting the use of technology in a teaching and learning environment of a rural South African university.
Findings	The findings illustrated a continuous growth in use of the Learning Management System (LMS). However, access to technology proved to be a major concern since 92% of student respondents indicated that they had to wait for access to a computer. In addition, the study found that there is a perception amongst some academic staff members that UL students have their own devices which they use for accessing online content. The study showed that 92% of the students are reliant on the Computer Labs for accessing computers. Eighty percent of the academic community who responded to the questionnaire use the University's LMS. The biggest factor influencing technology adoption was found to be Student Encouragement (35%). The fact that 23% of staff respondents use technology for self-development purposes and only 22% use technology on their own accord is indicative of very low interest levels among academic staff members in the use of technology for teaching purposes. Such paltry interest levels in the use of technology have implications for the eLearning support team who have been given the mandate to promote and motivate for effective use of eLearning. In addition, very few staff respondents in this study indicated their willingness to include multimedia content in their courses, with only 9% using sound, 12% using video, 15% using discussion forums and 15% making interactive content available to students.

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