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CONTENTS

Editor's Introduction: Informatics and Digital Transformations

Lucienne Abrahams
Director, LINK Centre, University of the Witwatersrand (Wits), Johannesburg; and AJIC Corresponding Editor

Abstract
This thematic introduction briefly discusses the importance of pursuing research in informatics and digital transformations in Africa.

Keywords
digital transformation, universal access, Africa

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1. Studies in informatics and digital transformation

The theme for this issue arises from the extensive work of Nagy Hanna, a pioneer in the field of digital transformation studies, who has exhorted the academic community and the policy and regulatory communities to expend their energies and research resources towards charting and understanding the nature of the changes wrought in economy and society through the application and use of digital technologies. Hanna's latest book, *Mastering Digital Transformation*, is reviewed in this issue. His work draws our attention to the need to engage in studies across the range of focus areas necessary to achieving a holistic understanding of digital transformation, including understanding of: transformation in key economic sectors; transformation in enterprises; transformation in government; modalities for fostering digital inclusivity; and building smart cities. Hanna also emphasises the need to incorporate consideration of foundational digital transformation elements such as an enabling ICT industry, the human resources necessary for digital innovation and adoption, enabling policy and regulation, and enabling institutions and leadership. Studies in informatics, including information processing, information systems design, and engineering for digital transformation, are all relevant to enhancing the knowledge base of digital transformation studies.

In which journals are authors publishing on informatics and digital transformation in Africa? First, a large number of journals are published in a wide range of knowledge fields related to digital technologies and their effects. These journals serve the scholarly communities working in particular aspects of the broader disciplinary grouping of digital technology studies, whether from an arts perspective, an engineering perspective, or a policy perspective, among others. In some cases, knowledge fields are even more specialised, with particular journals publishing on e-government or government information. Second, vast numbers of articles on digital technologies and their effects are also published in field-specific journals in fields other than those directly related to digital technologies and digital media: fields spanning knowledge from agriculture to zoology. These journals enable scholars and students in these particular fields to publish and read about the particular types of digital transformation occurring in their fields and disciplines.

Many African scholars of digital transformation publish in both types of journals – those focused on digital technologies and those field- and discipline-specific journals that publish selected articles on digital technologies and their effects in the particular field of study. *The African Journal of Information and Communication (AJIC)* seeks with its "informatics and digital transformations" thematic issues, including this issue, to bring together articles from across a broad range of knowledge fields – both digital-technology-specific and field- or discipline-specific – in one thematic publication, in a common space where a wide range of focus areas can appear together. The aim is to create a publishing space for studies situated in any aspect of informatics and digital transformation. Thus, discussions of digital transformation in the economy, in the social sphere, in communities, in the practice of science, and in many other forms and aspects of digital transformation on the African continent,

can appear in one *AJIC* thematic issue, fostering contemplation of both the singular and cross-cutting issues relevant to the emergence of digital societies, irrespective of national or regional differences.

2. The range of digital transformations covered in this issue

In this *AJIC* Issue 18, three articles provide a sense of the range of digital transformations currently underway on the African continent. Scholtz et al.'s article on gamification as a means to improving career knowledge establishes the importance of thinking about educational outcomes, as well as health goals and other social goals, as opportunities for creating games to foster achievement. Kiptoo, Gerber and Van der Merwe present a view of the design of informatics for more effectively studying biodiversity, through utilising digital technologies to enable citizen participation, through crowdsourcing, and through taxonomic tagging for the purposes of species identification and knowledge enrichment. Maharaj and Naicker, in their study of LinkedIn use in South Africa, analyse the value created through making personal knowledge capacities visible in online social networks, and provide an indication that firms' use of such online social platforms offers greater potential value than is generally recognised. The thematic report by Mbanaso directs our attention to the growth in international cyber conflict and the need for heightened African research in this area.

Van Biljon's article on development informatics research provides a useful foundational exploration for the two articles that it precedes. Van Biljon persuasively argues, in her abstract, that "[i]ndigenous or local researchers from developing countries have not made a leading contribution to development informatics (DI) or information and communication technologies for development (ICT4D) research". The two articles that follow Van Biljon's show the richness that emerges from efforts to progressively shift the reality that Van Biljon identifies, i.e., both articles contribute meaningfully to the goal of building a corpus of African development informatics knowledge. The Van Zyl and Sabiescu item provides findings from research into digital technology deployment in poorly-resourced South African schools, while Ezema addresses reproductive health information needs among rural women in Nigeria.

The article by Dlamini, Lugayizi and Esiefarienrhe presents an important area for continued research, as increasing demand is placed on the capacity of networks to offer quality of service for video streaming on the Internet. Greater attention to research on network engineering and its supporting role in development informatics is required with respect to future uses of the Internet, such as video streaming, in Africa.

3. Universal access in an African digital transformation context

The six articles and thematic report in this AJIC issue each present an implicit perspective on universal access requirements in the contemporary African digital ecosystem as we approach the end of the second decade of the 2000s. The requirements for universal access have advanced far beyond access to voice or Internet. In Africa,

we now live in an era where high levels of data usage via mobile Internet access and continuous connectedness are characteristic of economic and social development of households and nations. Universal access challenges for voice and Internet that were not answered in the first decade of the 2000s, combined with the greater complexity associated with the digital innovation and regulation required for effective universal access in this decade, have created an ever more difficult set of challenges for policymakers, regulators, Internet service providers, operators and digital innovators. Far from solving the universal access question, Africa's ICT ecosystem continues to produce new access challenges for African countries that are resource-poor or digital-strategy-poor. If more than a few people are to benefit from the gamification, or online social networks and technology-enabled schools, which are discussed in this issue, then it is a necessity that available funds and resources be directed towards appropriate investment in universal digital infrastructure access, use and innovation.

In 2017 and beyond, access goals on the African continent must focus on, among others, online education in and out of school, online access to career knowledge 24/7/365, building online communities of practice for scientific study, online health, and online knowledge-sharing. It is these directions where empowerment now lies. Not that the traditional forms of empowerment (via income, assets, all forms of infrastructure, and services) are no longer essential; they certainly are. Nevertheless, personal and community empowerment, through the various forms of educational and health content and general access to knowledge that is available online, are integral to enabling these traditional forms of empowerment.

Universal access to what? Universal access where? The combination of personal or shared devices, mobile voice, (mobile) broadband infrastructure, Internet services and online services, in the home or in walking distance, at affordable prices, at low or no cost – this is the what. Digital transformation of economy and society can advance through universal access to mobile voice and mobile broadband for the 50% or more of the population of the African continent that resides in rural and remote places – this is the where.

4. Learning by editing

AJIC is reviewed, edited and published by academics interested in the process of knowledge-making and knowledge evolution on the African continent. In addition to the value gained by the authors, to whom we are grateful for their contributions, significant value is also gained by the editorial team, as we engage with the submissions, and as we explore the reference materials cited by the authors, the vast majority of which are freely available online. Accordingly, significant author and editor energy goes towards ensuring that the citations linking to online works, in the articles' reference sections, are accompanied by working URLs or accurate digital object identifiers (DOIs).

I urge scholars to continue to treat *AJIC* as a platform for presenting research findings situated at the cutting edge of investigating African informatics and digital transformations.

ARTICLES

Design and Evaluation of a "Gamified" System for Improving Career Knowledge in Computing Sciences

Brenda Scholtz
Head of Department, Department of Computing Sciences, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa

Larissa Raga
Student, Department of Computing Sciences, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa

Gavin Baxter
Lecturer, School of Engineering and Computing, University of the West of Scotland

Abstract
"Gamification", or the use of game elements outside the gaming context, is a recent trend in learning approaches and has been used to digitally engage and motivate people to accomplish their learning objectives. The study described in this article investigated components of a gamification system and the impact of these components on user experience, usability and education usability. The Mechanics, Dynamics and Aesthetics (MDA) classification framework for gamification design was used to guide the authors' design of a gamification system intended to improve learners' knowledge of careers in computing sciences (CS). Criteria for evaluating e-learning systems were derived from literature and used to extend the MDA framework via addition of criteria for evaluating usability, user experience (UX) and educational usability of a gamification system. The extended MDA framework was found to be successful in guiding the design, development and evaluation of the system prototype, and the results gathered from the summative usability evaluation indicated that positive UX and educational usability were achieved. The results suggest that gamification designed for UX and educational usability can potentially play an important role in equipping young people in South Africa with a knowledge of CS-related careers.

Keywords
computing sciences (CS); gamification; Mechanics, Dynamics and Aesthetics (MDA) classification framework; usability; user experience (UX); educational usability

Recommended citation
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1. Introduction

A recent Employment Projections report by the United States Bureau of Labor predicted that jobs listed under Computer Occupations were set to increase by 17.7 %, from 3,682,000 in 2012 to 4,333,000 in 2022 (US Bureau of Labor Statistics, 2015). The report also predicts that there will be 1,240,000 job openings due to growth and replacements over this period. The four fastest-growing industries in dollar terms are forecast to be in information and communications technology- (ICT-) related industries. In South Africa, similar predictions have been made. The 2014 Joburg Centre for Software Engineering (JCSE) ICT Skills Survey estimated that there were about 40,000 ICT job vacancies in South Africa, and 59% of respondents said that the skills shortage was affecting company viability (Schofield, 2014). The 2014 Financial Services Sector Assessment Report (Western Cape Government, 2014) also showed that there was a large shortage of ICT skills in South Africa.

Within the broad range of ICT fields, "computing sciences (CS)" is an umbrella term that refers to both Computer Science and Information Systems disciplines at universities, faculties and departments worldwide (NMMU Computing Sciences, n.d.). Zwang (2010) states that CS has the highest job demand by employers among Science, Technology, Engineering and Mathematics (STEM) job disciplines. Schnabel and White (2014) concur, reporting a large number of STEM jobs in ICT, particularly in CS.

Morrison and Preston (2009) found that while the demand for CS graduates grew between 2000 and 2009, the number of applicants for CS-related career fields experienced a significant drop during the same period. An international drop in the number of enrolments for degrees in CS documented by Jacobs and Sewry (2009) suggested that there may at times be a scarcity of learners interested in these fields (Jacobs & Sewry, 2009). According to Calitz (2010), the primary reasons for the shortage of CS learners are negative perceptions about the ICT field, lack of sufficient ICT career information, and limited knowledge of the job opportunities available in the ICT industry. Meanwhile, Carcary, Sherry, McLaughlin and O'Brien (2012) found that a challenge experienced by learners at educational institutions was that they did not receive proper guidance in selecting a career path that matched their desired field of study.

The study outlined in this article sought to examine whether "gamification" could be used to broaden learners' knowledge of CS careers and expertise. According to Ernst and Clark (2012), in the science discipline learning systems that promote enthusiasm and engagement among learners, while improving their skills and abilities, have become a priority. Since its introduction, gamification has evolved into a common learning tool to enhance classroom tasks and has been proven to improve development in visual knowledge amongst learners (Ernst & Clark, 2012; Gee, 2003). And the use of gamification can have potential benefits for education scenarios where learners

need to be driven to participate in learning activities (Harman et al., 2014).

The term gamification was derived from the industry of digital media (Deterding et al., 2011b). The first known use of the term stems back to 2008, and more widespread use began in 2010 (Deterding et al., 2011a). Landers (2014, p. 752) defines gamification as "the use of game attributes […] outside the context of a game with the purpose of affecting learning-related behaviours or attitudes". According to Erenli (2013, p. 7), "gamification is the use of game elements in contexts that had originally no link to game related elements". Domínguez et al. (2013) define gamification as the use of game elements and design in non-game environments to influence user engagement. Gartner, a company that specialises in IT research, has redefined this definition as the application of both experience design and game mechanics to motivate and engage people to accomplish their objectives (Burke, 2014; Growth Engineering, 2015).

A related concept to gamification is "serious games". A serious game is a fully-fledged game for non-leisure purposes, including serious applications such as training or learning (Deterding et al., 2011a). While these two terms "gamification" and "serious games" are fundamentally different, the dissimilarity can at times be slightly blurred. According to Deterding et al. (2011a, p.12), while serious games fulfil all the conditions for being a game, "gamified" applications merely use some of the design elements of games.

An explosion of interest has occurred in recent years in using gamification to make non-game applications more enjoyable and engaging (Reeve, 2014). Gaming strategies can now be seen in a wide range of contexts, including business (gamified marketing campaigns and loyalty programmes), health (the gamification of fitness through programmes like Wii Fit and Nike+), government (the application of gamified "nudge" tactics and behavioural economics), and military (war games and simulations).

Game-based learning is not a new concept. Effective teachers and instructors have always understood the power of games to motivate and inspire. Whether via use of chess to develop strategic thinking, backgammon and Monopoly for mental arithmetic, Scrabble for spelling and vocabulary, or driving and flight simulators for an understanding of how to control sophisticated machines, games make learning fun and more effective than non-game approaches. The concepts of gamification have also been used in the design of systems for learners who wish to learn academic subjects and skills as preparation for an external test, or to explore the content for their own enjoyment (Ibáñez et al., 2014; Iosup & Epema, 2014; Lee & Hammer, 2011).

However, gamification systems that provide career knowledge and advice are limited.

Plotr is one system that has included aspects of gamification for users seeking career advice (Plotr, 2016). Plotr includes a set of real-life, working-world simulations that users can explore to find out more about the industries they are interested in, by means of showing the their progress towards attaining certain levels through gamification. In addition, they earn titles for each level completed and a leader board then displays recommended careers. Hunicke, LeBlanc and Zubek (2004) established the usefulness of levels to measure progress and accomplishment in gamification.

Gamification is now quite an acknowledged term in the academic literature. However, there is a lack of empirical evidence regarding gamification, gamification methods used and the effectiveness of gamification (Hamari et al., 2014). While many studies report successful implementation of gamification in learning environments, one study – the implementation of a serious game for increasing a player's understanding and awareness of flood issues – proved a particularly difficult endeavour and was unsuccessful (Rebolledo-Mendez et al., 2009). The components and elements of serious games and gamification systems need to be planned and designed very carefully (Deterding et al., 2011a; Deterding et al., 2013). Guidance, based on empirical evidence of the user experience (UX) of these systems (Beier, 2014; Knaving & Björk, 2013), is needed regarding which components to include. The satisfaction of students with e-learning has been reported as depending on a good UX (Urh et al., 2015), where UX, as defined by International Organisation for Standardisation (ISO) 9241-210, represents a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service (ISO, 2009).

While some guidelines on how to make learning activities more motivating and engaging have been provided (Knaving & Björk, 2013), these are limited and need to be extended and empirically validated in different settings. A learning environment is not just a digital product; it is also an educational product aimed at achieving learning goals and objectives (Ssemugabi & De Villiers, 2010). Therefore, when designing and evaluating such environments, it is important to also consider the usability and educational usability of such systems (Squires & Preece, 1999; Ssemugabi & De Villiers, 2010). Usability has been defined by the ISO as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1997). This standard therefore identifies the three usability criteria as *effectiveness, efficiency* and *satisfaction* with which users are able to achieve their tasks.

There is a need to understand the effect of gamification mechanics, and elements, on different individuals (Codish & Ravid, 2014). Research has been done (Mekler et al., 2013) on how different elements of gamification affect human behaviour. However, additional research is required to investigate the elements that contribute to improved UX, usability and education usability, and the criteria that can be used for evaluating gamified systems (Ašeriškis & Damaševičius, 2014; Urh et al., 2015).

In our study, we identified the components of a gamification system, and the criteria that can be used for evaluating UX, usability and education usability of such a system. In addition, we developed and implemented the gamified system, within the context of a South African educational environment, in order to investigate the possible role of gamification in providing youth with knowledge about career choices in CS-related disciplines.

The next section discusses literature related to the gamification domain and proposes an extended gamification design classification framework. This is followed by a description of the research methodology used in the study, and then an outline of the usability evaluation's criteria and processes. The results of the evaluation are then outlined, followed by conclusions and recommendations for further study.

2. Components of gamification

The key to successful gamification is appropriate choice of elements of game mechanics to incorporate into the system (Meder & Jain, 2014). A theoretical model that is commonly used to describe how gamification works and the components that should be included in the design of a gamification system, is the Mechanics, Dynamics and Aesthetics (MDA) classification framework (Hunicke et al., 2004). The MDA framework enables one to consider the views of both the game's designer and player. The framework describes how the three layers (mechanics, dynamics and aesthetics) are perceived by designer and player on the grounds that both their perspective needs to be considered. Each of the three layers of the MDA framework can be thought of as a lens (i.e., perspective) on the game. Whilst the layers are separate, they are also causally linked. A small change in one of the three layers can impact on the other two. According to Hunicke et al. (2004), thinking about the player, who is the user, encourages experience-driven rather than feature-driven design. This approach is in line with the principles of UX, where devices are designed to fit the user and not the task (ISO, 2009). Accordingly, for the MDA framework discussion that follows, we give primacy to the user perspective, followed by that of the designer, beginning with aesthetics, and then moving on to dynamics and mechanics

Aesthetics

In the MDA framework, aesthetics refers to "the desirable emotional responses evoked in the player, when she interacts with the game system" (Hunicke et al., 2004). Users perceive aesthetic elements as ultimate goals that they would like to achieve from the system, while game designers use aesthetic elements to determine the emotional state generated by users. According to Raymer (2011), aesthetics correspond with the experiences of users and are intended to be fun. Schell (2015) refers to aesthetics as a combination of game mechanics and dynamics that produce emotions for the user from the game play. Goals are one aspect of aesthetics and need to be spread across the system as stages that the learner needs to complete by using their knowledge (Raymer, 2011). Aesthetics use game mechanics and dynamics to

provoke an emotional response from the user. When describing the aesthetics of a game, it is necessary to use a more specific vocabulary than generalised words such as "fun" and "gameplay". Some examples of this vocabulary are:

- sensation: the game as a sense-pleasure
- fantasy: the game as make-believe
- narrative: the game as a drama
- challenge: the game as an obstacle course
- fellowship: the game as a social framework
- discovery: the game as unchartered territory (e.g., adventure/role-playing)
- expression: the game as self-discovery
- submission: the game as a pastime.

Each game pursues multiple aesthetic goals in varying degrees (Hunicke et al., 2004). For example, the computer game The Sims includes discovery, fantasy, expression and narrative, while the game of charades includes fellowship, expression and challenge. While both games are "fun", it is more informative to consider the aesthetic components that create the player experience. Reiners and Wood (2015) suggest that most games obtain the fun aspect from the thrill of the competition and challenge characteristics that have been incorporated. According to Reiners and Wood (2015), the inclusion of a social component/framework, or "fellowship", serves as a strong motivator for users to continue playing a game. Discovery relates to a sense of wonder that is experienced by the user when finding something new in a game and can include an adventure or role-playing scenario. Users can also often express themselves and their personalities through playing a game. Expression is sometimes referred to as "self-expression" and refers to allowing people the opportunity to express their uniqueness and differentiate themselves from others (Da Rocha Seixas et al., 2016). An example is the use of an avatar of a person. Submission focuses on developing an interaction whereby the game becomes a hobby for the user, instead of the user only playing the game once (Hunicke et al., 2004).

Dynamics

Dynamics are the "run-time behaviour of the mechanics acting on player inputs and each other's outputs over time" (Hunicke et al., 2004). Dynamics work to create the aesthetic experiences, and are the aspects of a game that develop and maintain a desired UX. A key dynamic model identified by Hunicke et al. (2004) is challenge, which can be initiated by elements like time pressure and opponent interaction. Urh et al. (2015) identify elements of game dynamics as: status, competition, achievement and response (Urh et al., 2015). Achievement physically represents an accomplishment, whereas a response is an action that is expected from a user (Schonfeld 2010). Dynamics can also be thought of as guaranteeing that the user will experience activity loops that include feedback, action and emotion (Ibáñez et al., 2014; Werbach & Hunter, 2012).

Mechanics

Mechanics are the "particular components of the game, at the level of data representation and algorithms" (Hunicke et al., 2004). Mechanics appear as rules of the game for users, while designers perceive them as indications of the user's actions. They are the agents and objects, as well as the elements and their relationships in the game. Examples of mechanics are the shuffling of the cards in a card game, or the balls, clubs and water hazards in a golf game.

According to Hunicke et al. (2004), together with the content of the game, mechanics support the game's overall dynamics. The mechanics' components can include both gaming elements and rules (Ašeriškis & Damaševičius, 2014). Gaming elements make the game challenging and satisfying for the user, whereas the rules are supported by the elements to create a sense of accomplishment for users trying to reach certain levels of achievement. For example, the element could be points and the rule would be the set of conditions required in order to be awarded the points.

Raymer (2011) explains that one needs to include feedback and rewards to develop a successful gamification learning system. Feedback is used to inform the learners of the progress that they have made, to prevent them from getting confused, and can also foster a player's engagement (Petrović & Ivetić, 2012). Rewards can be used as one type of feedback to acknowledge learners for their effort (Raymer, 2011). Codish and Ravid (2014) propose that mechanics that are used for feedback can be classified as either personal feedback (such as points, badges and rewards), or comparative feedback (such as progress bars and leader boards). The following components are examples of mechanics:

- points: represent achievements that are obtained (Beier, 2014; Iosup & Epema, 2014; Mekler et al., 2013; Schonfeld, 2010).
- levels: represent stages or milestones that a player has reached in a task (Hunicke et al., 2004). Levels can also be used to measure progress and accomplishment (Hunicke et al., 2004), and are a direct way of accumulating experience/points (Iosup & Epema, 2014).
- badges: are awarded on the successful completion of a task or challenge (Hunicke et al., 2004) and can serve as goals that users wish to achieve (Beier, 2014; Iosup & Epema, 2014).
- virtual goods (Urh et al., 2015): points can sometimes be used to purchase virtual items (Kim, 2015).
- multiple lives and life loss: are used to provide users with the sense of empowerment to experiment with different approaches, secure in the knowledge that if they get something wrong, they can try again (Kim, 2015; Reiners & Wood, 2015).
- stories: themes, stories or scenarios that implement the narrative aesthetics goal (Darejeh & Salim, 2016).
- leader boards and progress bars: are used to display a comparison of a user's achievements (Beier, 2014; Iosup & Epema, 2014; Werbach & Hunter, 2012).

Several studies (Amir & Ralph, 2014; Codish & Ravid, 2014; Ibáñez et al., 2014; Zichermann & Cunningham, 2011) have incorporated the MDA framework into gamification systems. Some of these systems (Ibáñez et al., 2014) have been implemented in higher education contexts. Table 1 provides a summary of the elements recommended by several authors (Beier, 2014; Darejeh & Salim, 2016; Hunicke et al., 2004; Raymer, 2011; Schonfeld, 2010; Urh et al., 2015) for consideration for inclusion in a gamification system. These are classified according to the three MDA layers from the top down.

Table 1: Recommended gamification elements

Layer and component	Reference
Aesthetics	
Sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission	Darejeh and Salim (2016); Hunicke et al. (2004); Raymer (2011)
Dynamics	
Challenge (e.g., time pressure and opponent interaction) Fellowship (e.g., sharing information) Expression (e.g., achievement, personalised characters)	Darejeh and Salim (2016); Hunicke et al. (2004); Reiners and Wood (2015); Schonfeld (2010); Urh et al. (2015)
Mechanics	
Stories Points, levels, badges, virtual goods and multiple lives/life loss (personal feedback) Leader boards and progress bars (comparative feedback)	Beier (2014); Codish and Ravid (2014); Schonfeld (2010); Urh et al. (2015)

The MDA classification framework for gamification proposed by Hunicke et al. (2004) does not include criteria for evaluating these systems. Thus, we extended the framework (see Figure 1 below) to include evaluation criteria: (1) usability, in terms of efficiency, effectiveness and satisfaction (IS0, 1997); (2) UX (Beier, 2014; Deterding et al., 2011a; Knaving & Björk, 2013; Harpur & De Villiers, 2015; Urh et al., 2015) and (3) education usability (Harpur & De Villiers, 2015; Squires & Preece, 1999; Ssemugabi & De Villiers, 2010).

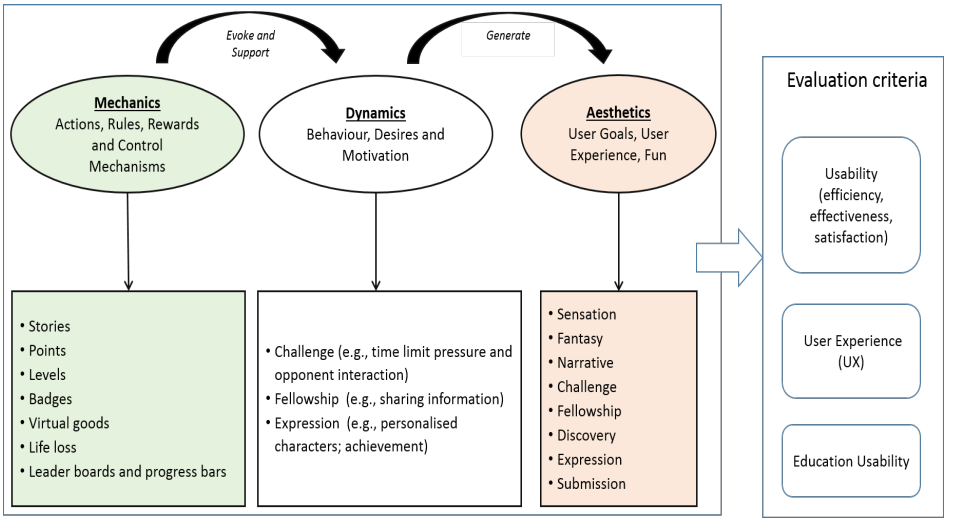


Figure 1: Extended MDA classification framework for gamification
Source: Adapted fromHunicke et al. (2004)

3. Research process and design

Questions and methodology

The primary research questions of our study were:

1. What are the components of gamification systems that improve usability, UX and education usability?
2. What are the UX, usability and education usability of students using a gamification system designed to improve knowledge of CS careers?

In order to answer these questions, a Design Science Research (DSR) methodology was used. The DSR methodology involves the procedure of designing an artefact to solve a problem, to contribute to research, to evaluate designs, and to deliver results to a suitable audience (Hevner et al., 2004). The DSR has been used in several learning studies, including use by El-Masri and Tarhini (2015) to develop a theoretical artefact (a set of design principles) for educational games. The artefacts of our study were the CS Careers gamification system that we developed, and our theoretical framework (the extended MDA framework outlined in Figure 1), which guided the design and evaluation of CS Careers. In line with the DSR methodology, we conducted several iterations for the literature review, the development of the artefacts, and the evaluation of these artefacts.

System design

Our extended MDA classification framework for gamification (Figure 1) was used to guide the design and development of the CS Careers system at Nelson Mandela Metropolitan University (NMMU), by one of the authors of this paper. CS Careers is an interactive, web-based system that contains information about a selection of CS careers. The system enables learners to view CS career content, perform a set of related pre-defined tasks and, as a result, earn a set of rewards (for example, points and badges) for the tasks that they successfully complete (Figure 3). The system therefore implements various gamification elements with the aim to motivate learners to use, and encourage their engagement and participation with, it, and ultimately improve their knowledge of CS careers. The MDA framework recommends deciding on aesthetics first, then design mechanics required to achieve the aesthetic goals, and finally dynamics.

The primary *aesthetics* goals of the CS Careers system were identified as expression, narrative, discovery and challenge. Expression was identified as a key goal since the objective of the game was to be a voyage of self-discovery to learn more about the various careers in the CS industry. The narrative goal was implemented by the job profiles and story created for each employee character that was presented to the user, either through audio or a text bubble. The discovery aesthetic related to the role of the player as one of the various employees in a typical IT office. Examples of these employees/characters in CS Careers are a Web Developer, Project Manager and/or Programmer. Challenge was incorporated into the design of the system by allowing the player to perform simple tasks that a typical CS employee would be expected to do. For example, as part of his/her job function, a Web Developer would need to know how to design a web page; thus that would be one of the tasks in the CS Careers system that the player would need to complete.

The *dynamics* elements of the MDA framework were implemented with the expression goal playing a key role in the form of personalised characters that represent the various employees in a typical IT office. The home page of the CS Careers system is the environment of a typical IT department or IT company. The users can explore this IT office environment and interact with each of the employees in various locations of this environment. Each character encounters "challenges" that are linked to a specific set of tasks that are typical of that employee (e.g., Web Developer), and these tasks are activated by clicking on or hovering over the employee. For example, the Project Manager's tasks require the user to select the various activities necessary for IT project planning. If the user selects the correct activities in the right order, he/she is rewarded with various gamification elements and in this way the achievement goal is supported.

The *mechanics* elements of the MDA framework were implemented in CS Careers through points, badges and life loss. The user can earn points for each office area

visited and badges for each set of tasks completed, but loses a life for each unsuccessful task attempted. As determined by the MDA framework, the success or failure of these tasks and the use of the MDA mechanics are then expected to result in emotions experienced by the user in the aesthetics layer. For example, a reward such as a badge will provide the user with recognition for the correctness of his/her actions and contribute to the challenge aesthetic. He/she can also view the recreational area of the office environment, which displays a summary of his/her achievements based on the results of tasks performed in the system.

Figure 2: CS Careers home page

In accordance with the iterative nature of DSR, an evolutionary prototyping process was applied to the design and development of the CS Careers system. Formative evaluations were performed during the process, on the basis of which the prototype was improved over three iterations, before the fourth and final one was developed. The final prototype was then evaluated by means of a final summative usability evaluation involving NMMU students, as described below, for which ethical clearance was obtained from NMMU.

Usability evaluation

Participants, environment, procedures

No fewer than eight participants should be involved in a usability study to ensure that valid summative statistical analyses are produced (Scholtz, 2000). For this reason, 12 students at NMMU were selected to participate in the usability evaluation. Systematic

sampling was used, whereby a specific sample of participants was identified (Tullis & Albert, 2013), based on the criteria of age and programme of study. Students between the ages of 18 and 20 years were selected to represent the target group of the study. (Studies have shown that early adults are those between 17 and 22 years of age, and that it is during this stage that they make choices about adult life, such as career choices (Levinson, 1994). Since the intended users are scholars in the final year of high school who are in the process of making a career choice, the age profile of the selected participants was similar to the intended profile of the user). It was assumed that the students enrolled for the CS qualifications at NMMU would be more familiar with the content of the CS Careers site. Therefore, the sample of participants included non-CS students in order to avoid bias towards CS students. The participants were first-year students from the Departments of CS and Business Management at NMMU.

For the purpose of evaluation, participants were required to complete five tasks on the CS Careers system. (They were required to complete an online consent form prior to the commencement of performing the list of tasks.) The evaluation was conducted in the controlled setting of a computer laboratory situated in the NMMU CS Department, as a controlled setting allows the evaluator to control the users' activity while using a system (Rodgers et al., 2011). The participants were encouraged to ask the evaluator (who is one of the authors of this article) for assistance should they require any throughout the evaluation.

Instruments, metrics

The objective of the summative usability evaluation was to evaluate the (1) usability, (2) UX and (3) education usability of the system, in terms of the extended MDA framework (Figure 1).

In order to measure usability, two metrics were recorded by the evaluator: effectiveness and efficiency. Task success was used as a measure of effectiveness, and time-on-task was used to measure efficiency (Tullis & Albert, 2013). Task success was based on how many of the tasks were successfully completed by each participant. Participants were informed that they were being monitored but were not given any time constraints for completion of the tasks. They were asked to write down answers to certain questions on a printed task list. The correctness of these answers as well as the scores they obtained for each task within CS Careers determined their task success. Time-on-task was measured to determine the amount of time the participants took to complete the set of tasks.

For evaluation of UX and education usability, we initially considered using the Learning Object Review Instrument criteria (Leacock & Nesbit, 2007). This was then rejected, because it did not address aspects of engagement and motivation, which we had determined needed to be measured to ascertain the success of a

gamification system. Harpur and De Villiers (2015) propose criteria specifically designed to evaluate learning environments, and their criteria incorporate aspects of UX and education usability. Accordingly, we adopted a subset of the Harpur and De Villiers criteria for the evaluation: four UX criteria (and their sub-criteria) and three education usability criteria (and their sub-criteria), as outlined in Table 2 below.

Table 2: UX and education usability criteria and sub-criteria

User experience (UX)
1. *Emotional issues* 1.1. The tasks within the system are motivating to learn more about CS careers 1.2. The tasks within the system are fun 1.3. The system encourages participation 1.4. This way of learning about CS careers is exciting 1.5. This way of learning about CS careers is interesting
2. *User-centricity/engagement* 2.1. The gamification elements enhanced my engagement with the system 2.2. The visual representations of the CS roles enhanced my engagement with the system 2.3. The auditory information about the CS roles enhanced my engagement with the system 2.4. The textual information about the CS roles enhanced my engagement with the system
3. *Appeal* 3.1. I was encouraged to explore the system 3.2. The experience was visually appealing
4. *Satisfaction* 4.1. The experience added fun to the learning opportunity 4.2. This way of learning about CS careers is motivating 4.3. A satisfying sense of achievement was felt 4.4. The system encouraged me to engage with the content
Education usability
1. *Clarity of goals, objectives and outcomes* 1.1. The goals are clearly set out and objectives and expected outcomes for learning are clear
2. *Error recognition, diagnosis and recovery* 2.1. Mistakes can be made, affording users the chance to learn from them 2.2. Help is provided to recover from errors
3. *Feedback, guidance and assessment* 3.1. Prompt feedback on assessment and progress is provided 3.2. Guidance is provided about the tasks and construction of knowledge going on 3.3. Activities are graded with grades providing instant feedback and correction

Source: Adapted from Harpur and De Villiers (2015)

The criteria selected from Harpur and De Villiers (2015) for the UX category were those oriented towards the ability to induce the emotive experiences of the user, namely (1) *emotional issues*, (2) *user-centricity/engagement*, (3) *appeal,* and (4) *satisfaction*.

According to Harpur and De Villiers (2015), *emotional issues* can be measured by the level of motivation, fun, participation, excitement and interest the users experience by performing the tasks within the system. The emotional aspect is also supported by the aesthetics layer in the MDA framework, which relates to the

"emotional response" of the user (Hunicke et al., 2004). *User-centricity* relates to the user's personal judgment of the system and its components (Harpur & De Villiers, 2015). Another important criterion for evaluating gamification, related to user-centricity, is the level of *engagement* (Barata et al., 2013; Beier, 2014; Burke, 2014; Petrović & Ivetić, 2012). While there is evidence that gamification improves student engagement, this is not a guarantee of success and is one of the main challenges of gamification design (Ibáñez et al., 2014). Deterding et al. (2011a) explain that gaming elements can create an experience (UX) the user desires, and can also motivate user engagement while performing an activity. Therefore, the use of these elements can be used as an expedient approach for making gamification systems engaging and enjoyable to use. Other studies have also reported the successful adoption of gamification in learning environments by identifying increased engagement from learners with the learner tasks (Darejeh & Salim, 2016; Da Rocha Seixas et al., 2016; Ibáñez et al., 2014). User engagement contributes towards a motivated UX around the functionality and content of the system (Barata et al., 2013; Browne et al., 2014). However, gamification designers should provide a facility for educators to control the level of student engagement, in order to strike a balance between playfulness and educational needs (El-Masri & Tarhini, 2015). In other words, the game should acquire high task engagement from the player, but without complete immersion or addiction to the game. Game addiction refers to a pathological use of the game, while high engagement is defined as the non-pathological usage that can be controlled by the user. The researchers of this study therefore propose that engagement can be used as a criterion of UX for evaluating gamification systems. The impact of the gamification elements implemented in the design (for example visual, auditory and textual information) on the user's engagement with the system can be measured using criteria related to *user-centricity* and *engagement*.

Appeal can be measured by the user's opinion of visual elements and aesthetics of the system's user interface (Harpur & De Villiers, 2015). *Satisfaction* can be measured by the user's feelings of fun, motivation and achievement. In this way, the success of using gamification elements to encourage engagement and ultimately a motivated UX can be measured by these four categories.

In order to measure education usability, the criteria we took from Harpur and De Villiers (2015), were those focused on the relationship between the learning objectives and the content of the system, namely: (1) *clarity of goals, objectives and outcomes*, (2) *error recognition*, *diagnosis and recovery*, and (3) *feedback, guidance and assessment* (Harpur & De Villiers, 2015, p.10).

According to Ssemugabi and De Villiers (2010), effective feedback, guidance and assessment should be provided to the learner for the ultimate adaptation of learning content. The use of feedback as one of the criteria supports Petrović and Ivetić's (2012) argument that a learner's engagement can be fostered through providing the

learner with feedback on progress.

The participants were required to rate each of the 21 statements (see Table 3 below) in the two categories (UX and education usability) from 1 to 5 (Likert scale), where 1 represented "strongly disagree" and 5 represented "strongly agree". The questionnaire also included two open-ended questions, which were used to allow the participants to express their opinions by stating the three aspects they found best, and the three aspects they found worst, about the system. In this way, both closed- and open-ended qualitative data were collected.

4. Evaluation results

Participant biographical information

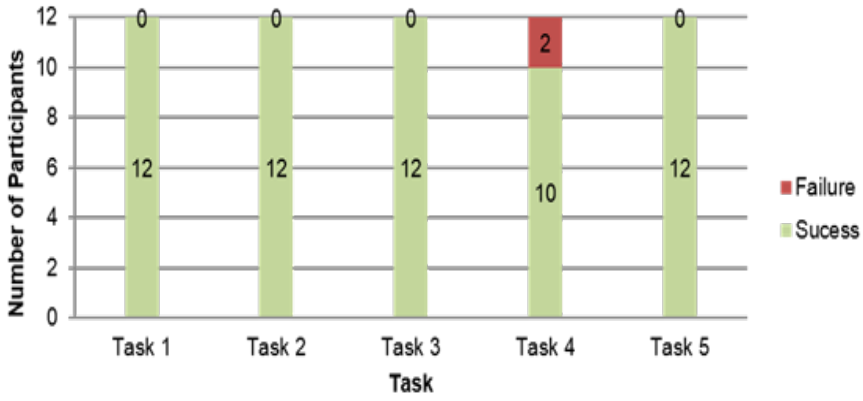
The participant sample consisted of 12 students, with an equal number of males and females. The majority (67%) of the participants were enrolled for CS qualifications, while the remaining students were enrolled for a business degree at NMMU.

Usability results: Effectiveness (task success) and efficiency (time-on-task)

A binary scale (1 = task success, 0 = task failure) was used to measure effectiveness. Task success is sometimes referred to as the completion rate of a task and is a fundamental usability metric (Tullis & Albert, 2013). This scale requires two different values to be assigned in a task: one for success and the other for failure. If users cannot accomplish their goals or tasks, then nothing else really matters. In this study successful completion meant that they could complete the task in the CS Careers system with or without assistance from the test facilitator. The success of Task 1 was measured by the participant's ability to open the provided link and navigate to the landing page of the CS Careers system. The participant passed Task 2 if he/she managed to complete Task 2 and proceed to Task 3. The success of Tasks 3, 4 and 5 were obtained by measuring correctness of the answers provided on the printed task list.

The only task that did not have 100% success was Task 4 (Figure 3 below). Task 4 had an 83% success rate, because two participants could not complete certain elements of the task. Task 4 required completion of all tasks within the system related to the role of CS employees. The participants were required to obtain a certain score in order to pass Task 4. The two participants who did not obtain the required score were not enrolled for a CS qualification and it could be deduced that these tasks were too difficult for this student profile.

Figure 3: Effectiveness (task success vs failure)



Efficiency (time-on-task) was measured by the amount of time (in minutes) it took for each participant to complete the entire task list. It was found that the longest a participant took to complete the tasks was 23 minutes. The least amount of time that a participant took to complete all of the tasks was 11 minutes. The average time that the participants took to complete the tasks stipulated was 15.6 minutes. This average time was considered acceptable, because it was less than the reasonable expected time (calculated by multiplying an expert's task time by 1.5). Therefore, it can be deduced that most of the participants were able to efficiently perform the tasks.

UX and education usability results

When analysing the Likert scale ratings for UX and education usability, the following statistical ranges were applied: negative (1 to 2.6), neutral (2.6 to 3.4), and positive (3.4 to 5). Each criterion's score was generated by averaging the statement scores for that criterion.

All four criteria in the UX category were rated positively. The criterion in the UX category that received the highest overall mean rating was *appeal* (μ=4.7) (Figure 4 below). The remaining three criteria for UX all received the same overall mean rating (μ=4.4). The positive results for the *appeal* category indicate that the participants found the experience visually appealing.

In the education usability category, all three criteria were rated positively (Figure 5 below). The criterion *clarity of goals, objectives and outcomes* received the highest overall mean rating (μ=4.7) in the education usability category, whereas the lowest-rated criterion was *error recognition, diagnosis and recovery* (μ=4.3).

Figure 4: User experience (UX) criteria results

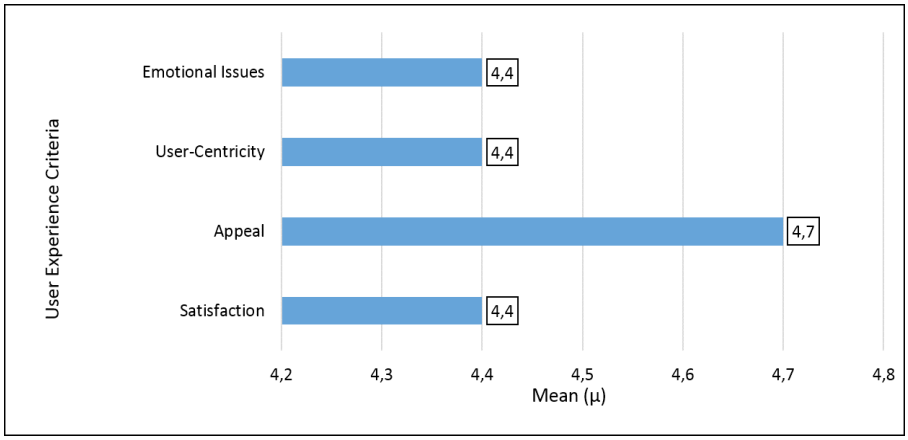
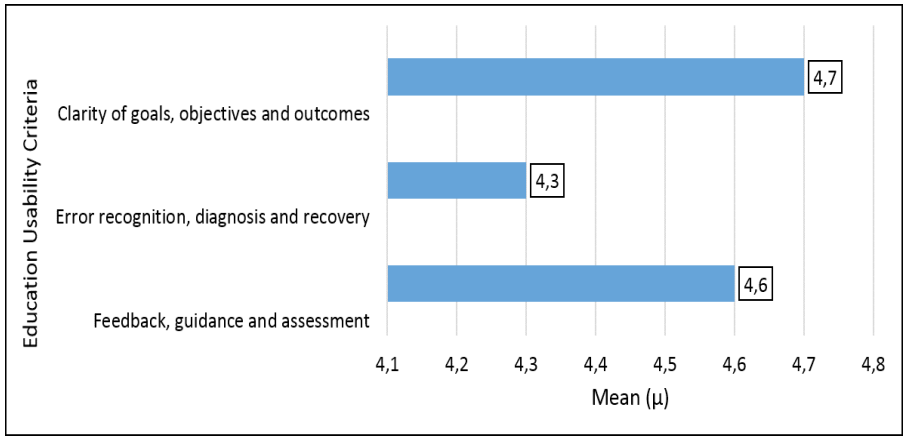


Figure 5: Education usability criteria results



All 21 of the sub-criterion statements – across the four UX criteria and three education usability criteria – had mean ratings in the positive range (see Table 3 below). In the UX category, the statement that obtained the highest positive response was "The experience was visually appealing" (μ=4.9), which falls under the *appeal* criterion. This result confirms the Harpur and De Villiers (2015) contention that visual appeal is an important criterion for evaluating UX. The second-highest-ranked statement (μ=4.8) in the UX category was "The gamification elements enhanced my engagement with the system", under the *user-centricity/engagement* criterion. The

third-highest-ranked response (μ=4.7) in the UX category was for the statement "The experience added fun to the learning opportunity", under the *satisfaction* criterion. The participants also provided positive feedback (μ=4.6) in response to the statement "The visual representations of the CS roles enhanced my engagement with the system", under the *user-centricity/engagement* criterion. These positive responses confirm studies (Barata et al., 2013; Browne et al., 2014; Ibáñez et al., 2014) stating that gamification influences user engagement.

Table 3: UX and education usability sub-criteria results

User experience (UX)	**Mean (μ)**	**Std. Dev. (σ^2)**	**Min.**	**Max.**
Emotional issues				
The tasks within the system are motivating to learn more about CS careers	4.2	0.39	4	5
The tasks within the system are fun	4.3	0.45	4	5
The system encourages participation	4.6	0.67	3	5
This way of learning about CS careers is exciting	4.4	0.67	3	5
This way of learning about CS careers is interesting	4.5	0.67	3	5
User-centricity/engagement				
The gamification elements enhanced my engagement with the system	4.8	0.45	4	5
The visual representations of the CS roles enhanced my engagement with the system	4.6	0.51	4	5
The auditory information about the CS roles enhanced my engagement with the system	3.8	1.03	2	5
The textual information about the CS roles enhanced my engagement with the system	4.3	0.78	3	5
Appeal				
I was encouraged to explore the system	4.5	0.52	4	5
The experience was visually appealing	4.9	0.29	4	5
Satisfaction				
The experience added fun to the learning opportunity	4.7	0.49	4	5
This way of learning about CS careers is motivating	4.2	0.39	4	5
A satisfying sense of achievement is felt	4.3	0.65	3	5
The system encouraged me to engage with the content	4.5	0.52	4	5
Education usability				
Clarity of goals, objectives and outcomes				
The goals are clearly set out; objectives and expected outcomes for learning are clear too	4.7	0.49	4	5
Error recognition, diagnosis and recovery				
Mistakes can be made affording users the chance to learn from them	4.6	0.51	4	5

Help is provided to recover from errors	4.1	0.90	3	5
Feedback, guidance and assessment				
Prompt feedback on assessment and progress is provided	4.5	0.80	3	5
Guidance is provided about the tasks and construction of knowledge going on	4.5	0.52	4	5
Activities are graded with grades providing instant feedback and correction	4.8	0.45	4	5

Within the *user-centricity/engagement* criterion of the UX category there were two statements related to textual and auditory presentation of the content. The participants rated the statement related to textual information, "The textual information about the CS roles enhanced my engagement with the system", higher (μ=4.3) than the statement "The auditory information about the CS roles enhanced my engagement with the system", which obtained the lowest mean rating (μ=3.8). Therefore, it can be deduced that the audio information within CS Careers was not completely successful in enhancing the participant's engagement with the system.

In the education usability category, the highest-rated statement (μ=4.8) was obtained from the statement "Activities are graded with grades providing instant feedback and correction", which is a metric of the *feedback, guidance and assessment* criterion. This confirms the findings of studies by Petrović and Ivetić (2012), who found that a learner's engagement can be fostered through feedback. The second-highest-ranked statement in the education usability category was "The goals are clearly set out, objectives and expected outcomes for learning are clear too" (μ=4.7). These results indicate that the system successfully provided the learners with the necessary learning outcomes, guidance, and feedback required to perform the tasks.

Results from responses to open-ended questions

The responses to the two open-ended questions at the end of the questionnaire - requiring the participants to list the three best and worst aspects of the CS Careers system - were analysed using thematic synthesis (Thomas & Harden, 2008). Based on the thematic synthesis, the participant responses were grouped and assigned to a set of positive and negative aspect categories. Thereafter, a frequency count (f) for each theme was calculated, in order to determine which aspects were most frequently mentioned by the participants.

In Table 4 below, the themes, frequency counts and sample comments are tabulated according to the most positive aspects of CS Careers. A total of seven themes were identified within the positive aspects category. The three most frequently identified positive themes were (1) *visual appeal and design* (f=10), (2) *CS career knowledge* (f=8) and (3) *gamification* (f=5). Out of the 12 participants, 10 reported positive issues related to the aesthetics of CS Careers and the *visual appeal and design* theme. The CS career knowledge theme related to improvement of knowledge of CS careers

and the majority (eight out of 12 participants) made comments confirming that their knowledge was improved. The high count of comments in the *visual appeal and design* theme confirms the results of a positive (μ=4.9) response that was provided by the participants for the UX *appeal* criterion. One participant stated that "The game looked appealing". Another stated that he/she enjoyed learning about the job descriptions of the different careers in the CS field. *Ease of use*, *characters*, *feedback* and *audio* were the other aspects that the participants praised about the system. Two of the participants reflected positively on the feedback provided by the system, which confirmed the above-mentioned contention that learners' engagement can be fostered through feedback (Petrović & Ivetić, 2012). This response was also supported by the overall positive rating (μ=4.6) that the participants provided for the *feedback, guidance and assessment* criterion under education usability.

Table 4: Positive aspects of CS Careers

Theme	Frequency count (*f*)	Sample Comments
Visual appeal and design	10	"The game looked appealing."
CS career knowledge	8	"The fact that I learned more about the job descriptions of the different careers in the computer science field."
Gamification	5	"The gamification made the task of answering questions more fun than it normally would've been."
Ease of use	3	"Easy user interface."
Characters	3	"Fun characters that portray the different employees."
Feedback	2	"The instant feedback about each task and being able to access a report sheet."
Audio	2	"The audio in the programme was good."

As shown in Table 5 below, a total of seven themes were identified by participants as negative aspects of the CS Careers system. And it was found that most of those listed by the participants related to the CS employee *tasks* (f=6). One participant stated that "Some tasks were not explained well enough". Other negative aspects were associated with the *audio* (f=5), *information* (f=4) and *level of difficulty* (f=4) of CS Careers. One participant suggested that "The sound aspect of the game could have been better". This response could be seen as contradicting the positive mean rating for the statement "The auditory information about the CS roles enhanced my engagement with the system" under the UX *user-centricity* criterion, but it should at the same time be recalled that the *audio* statement was rated the lowest (μ=3.8) among the four sub-criterion statements used to measure *user-centricity*.

Table 5: Negative aspects of CS Careers

Theme	Frequency Count (*f*)	Sample Comments
Tasks	6	"Some tasks were not explained well enough."
Audio	5	"The sound aspect of the game could have been better."
Information	4	"Life loss is unclear."
Level of difficulty	4	"The game was quite short and relatively easy."
Instructions	3	"Instructions not so clear."
Task discovery/navigation	3	"The tasks were difficult to find."
User error	2	"Allow room for user error."

The citing of *level of difficulty* as a negative dimension could also been seen as slightly contradictory, given that four participants stated that they found the game too short and the tasks too easy. However, one of the participants not enrolled for either a CS or IT qualification stated that the questions within the system required IT knowledge. (During the formative evaluations, the experts from NMMU who evaluated the system highlighted that certain tasks might be too difficult for non-CS students. For this reason, some of the tasks were reduced in complexity.). *Task discovery* and *user error* were the remaining negative aspects that were identified in the participants' comments. For example, one participant stated that "The tasks were difficult to find."

5. Conclusions and recommendations

Our research results suggest that gamification could be a worthwhile tool for deployment in response to the demand from employers for CS skills and the resulting need for enhanced knowledge of CS-related careers among the youth.

The CS Careers system was designed and evaluated according to the elements of our extended MDA gamification classification framework. All three evaluation criteria - usability, UX, and education usability - received generally favourable ratings by the usability evaluation participants, suggesting that the gamification elements enhanced the CS Careers system. These results provide additional support for the findings of Browne et al. (2014) and Da Rocha Seixas et al. (2016), and suggest that the MDA framework is useful in guiding design of a gamification system with an educational intent. The study also showed that both difficulty level and task creation are critical parts that should be carefully considered in the design process in gamification systems for education purposes. Another area found to be important for designers of gamification for learning is audio. The results showed that the participants preferred textual over auditory information about the employees/roles. Additional studies should be conducted in order to determine the reasons for this and the specific design criteria for auditory learning objects. The role of video could also be investigated.

Designers of gamification systems for career learning can potentially use findings from this study to guide their efforts to optimise usability, UX and education usability.

Future research could extend the study into other contexts, and also investigate the longitudinal implications of gamification systems for career knowledge and advice. And more detailed analyses of the relationships between specific gamification elements and usability, UX and education usability criteria could also be attempted.

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Towards Citizen-Expert Knowledge Exchange for Biodiversity Informatics: A Conceptual Architecture

Caroline Chepkoech Kiptoo
PhD Student, Department of Informatics, University of Pretoria

Aurona Gerber
Associate Professor, Department of Informatics, University of Pretoria

Alta van der Merwe
Professor and Head of Department, Department of Informatics, University of Pretoria

Abstract
This article proposes a conceptual architecture for citizen-expert knowledge exchange in biodiversity management. Expert services, such as taxonomic identification, are required in many biodiversity management activities, yet these services remain inaccessible to poor communities, such as small-scale farmers. The aim of this research was to combine ontology and crowdsourcing technologies to provide taxonomic services to such communities. The study used a design science research (DSR) approach to develop the conceptual architecture. The DSR approach generates knowledge through building and evaluation of novel artefacts. The research instantiated the architecture through the development of a platform for experts and farmers to share knowledge on fruit flies. The platform is intended to support rural fruit farmers in Kenya with control and management of fruit flies. Expert knowledge about fruit flies is captured in an ontology that is integrated into the platform. The non-expert citizen participation includes harnessing crowdsourcing technologies to assist with organism identification. An evaluation of the architecture was done through an experiment of fruit fly identification using the platform. The results showed that the crowds, supported by an ontology of expert knowledge, could identify most samples to species level and in some cases to sub-family level. The conceptual architecture may guide and enable creation of citizen-expert knowledge exchange applications, which may alleviate the taxonomic impediment, as well as allow poor citizens access to expert knowledge. Such a conceptual architecture may also enable the implementation of systems that allow non-experts to participate in sharing of knowledge, thus providing opportunity for the evolution of comprehensive biodiversity knowledge systems.

Keywords
conceptual architecture, knowledge exchange, species identification, crowdsourcing, knowledge transfer, ontology in information systems

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1. Introduction

Biodiversity management requires collection and processing of large volumes of data that change continuously in dimensions of time and space. One of the important datasets is data on species occurrences. Generally, an occurrence of an organism is recorded in three dimensions: identity (what), space (where) and time (when) (Graham, Ferrier, Huettman, Moritz, & Peterson, 2004). An occurrence record therefore consists of the organism's scientific name, the place it was observed and the date and time of the occurrence. Occurrence data, when recorded properly and conforming to scientific standards, may be combined with other biodiversity data and used for various purposes. These purposes may include conservation planning, biogeography studies, and border control and wildlife trade. Occurrence data is also a building block in generating species distribution maps, in phylogenetic studies and in several other thematic areas in biodiversity science that are dependent on species knowledge (Chapman, 2005; Pressey, 2004).

Recording of species occurrence data has long been acknowledged as an expensive exercise, more so when taxonomic experts are to be engaged on a continuous basis (Hardisty, Roberts, & The Biodiversity Informatics Community, 2013; Wiggins & Crowston, 2010). A multiplying factor to the cost of species monitoring costs, in most projects, is the requirement for expert participation and coverage over a long period of time and across vast spatial ranges. Furthermore, there are often "gaps" in the documentation of taxonomic knowledge and a shortage of experts in taxonomy, these two factors being commonly referred to as the "taxonomic impediment" (Dar, Khuroo, Reddy, & Malik, 2012; De Carvalho et al., 2005; Giangrande, 2003; Hardisty et al., 2013). In the developed world, the taxonomic impediment is an important challenge in biodiversity management. It has an even bigger impact on under-resourced communities within the developing world, where access to expert taxonomic knowledge is often an unaffordable commodity. In the community targeted by this research, fruit farmers in Kenya, it is necessary to identify fruit fly species to efficiently manage orchards and crops, because the different fruit flies species require different interventions (Ekesi, 2010; Ekesi & Muchugu, 2007; Rwomushana, Ekesi, Gordon, & Ogol, 2008).

Over the years, varying approaches have been employed to mitigate against the challenges posed by the taxonomic impediments. Citizen science projects, where interest groups consisting of non-biologists participate in recording occurrences, have been used to reduce species monitoring costs. In such projects, participating communities are equipped with the necessary skills of identifying the targeted taxonomic groupings and provided with field guides, identification keys and recording templates. A widely cited example in the field of biodiversity sciences is the Audubon Society's Christmas Bird Count[1] dating back to 1900. The Audubon project uses citizens to

1 See http://www.audubon.org

count bird species on Christmas day (Sullivan et al., 2009). Reptiles (Behler & King, 1979) and mushrooms (Lincoff & Nehring, 1997) are examples that have also been monitored using citizen science approaches.

Recent technological developments have led to the transformation of analytical processes in many sectors. In biodiversity sciences, Web technologies have enabled sharing of huge datasets that were previously confined to institutional and individual repositories (Graham et al., 2004). Web technologies also contribute towards new developments in the recording of occurrence data. Specifically, Web 2.0 has enabled the creation of platforms where amateurs or citizens can use their smart devices to record occurrences by uploading media files (images and videos) of the organism; date, time and place it was observed; and a simple description. These records are then manipulated, at a later stage, using identification expertise from mainly taxonomists and curators, making them valid scientific data (Mayer, 2010; Newman et al., 2012).

Participants in such platforms include amateurs who record observations without the scientific identification; citizen-experts with knowledge in certain organisms who can aid in identification of samples; and experts who have the formal training to reliably identify samples. For example, in iNaturalist[2] and Encyclopaedia of Life (EOL)[3] amateurs can record observations without scientific names and the organisms are later identified and validated by experts, thus ensuring that they are valid scientific records. The use of such platforms in species monitoring projects is on the rise, because, even though it does not alleviate the taxonomic impediment, it does assist with data collection. The result, however, is large volumes of data that need to be identified. Currently, there are over 680 projects recorded in the Biodiversity Information Standards (TDWG) database of biodiversity informatics projects (TDWG, 2016). However, most citizen science projects at present require experts or citizen-experts to provide organism identification services, and participants must therefore have sufficient knowledge in the taxonomy of the target species. The lack of sufficient taxonomic services is a bottleneck in citizen science projects and limits the possibilities for the data collected from these projects.

As stated, in several projects where citizens participate in biodiversity observations, identification services have been identified as a bottleneck, since it is not practical to engage taxonomists to perform repetitive tasks of identifying amateur recordings. On the other hand, the use of citizen-experts has limitations, since citizen-experts are often knowledgeable about only a limited range of species. In this research, the focus is on alleviating the taxonomic impediment, by enabling knowledge transfer between experts and citizens, through technology, as well as the crowd. Capturing taxonomic knowledge in an ontology and combining it with crowdsourcing techniques presents

2 See http://www.inaturalist.org
3 See http://eol.org

an opportunity to perform identification of organisms without the demand for full taxonomic knowledge and skills among participants. One of the goals of this concept is to expand the sources of identification services by using crowds to perform simple tasks online that result in identification. This will increase the capacity for amateur-recorded observations and also provide opportunities for gradual learning among participants and acquisition of basic knowledge on the organisms studied.

The opportunity presented by the possible synergy of ontological modelling and crowdsourcing led to the research question: What are the components of a conceptual architecture for citizen-expert biodiversity knowledge exchange using ontology and crowdsourcing technologies?

The next section discusses literature related to ontological modelling and to crowdsourcing. This is followed by a description of the research methodology used in the study and the conceptual architecture developed. The architecture is then evaluated via the results of an experiment of fruit fly identification, followed by conclusions and recommendations for further study.

2. Literature survey

Alleviating the taxonomic impediment with ontology and crowdsourcing has previously been investigated in the literature. One approach is capturing taxonomic knowledge in an ontology to allow access to expert taxonomic knowledge, as shown by Gerber, Eardley, and Morar (2014). In that approach, an ontology of expert knowledge, specifically the morphology of Afritropical bees, was captured and the ontology was integrated into an application for the identification of bees (Gerber et al., 2014). Capturing of taxonomic knowledge in an ontology and creating an ontology-based taxonomic key were explored and reported in Kiptoo, Gerber, and Van der Merwe (2016). However, that work was not sufficient, because the additional skill of being able to use taxonomic keys to fully identify an organism remains difficult for ordinary citizens to achieve.

The use of crowdsourcing to assist with online identification of amateur records has been explored, and there have been some promising results (Matheson, 2014). The iNaturalist project uses crowdsourcing techniques at species level, where participants identify a sample by assigning it a scientific name and the combined identification is aggregated to assist with record validation. However, this approach still requires significantly high levels of expertise in scientific identification, for participants to be able to perform the identification tasks. The identification tasks are largely performed by curators and not citizens. Finally, most of the smaller organisms, like the fruit flies, are assigned a family name identification and not a species name. This reduces the adequacy of the data, since certain classes of problems require organism identification up to the species level.

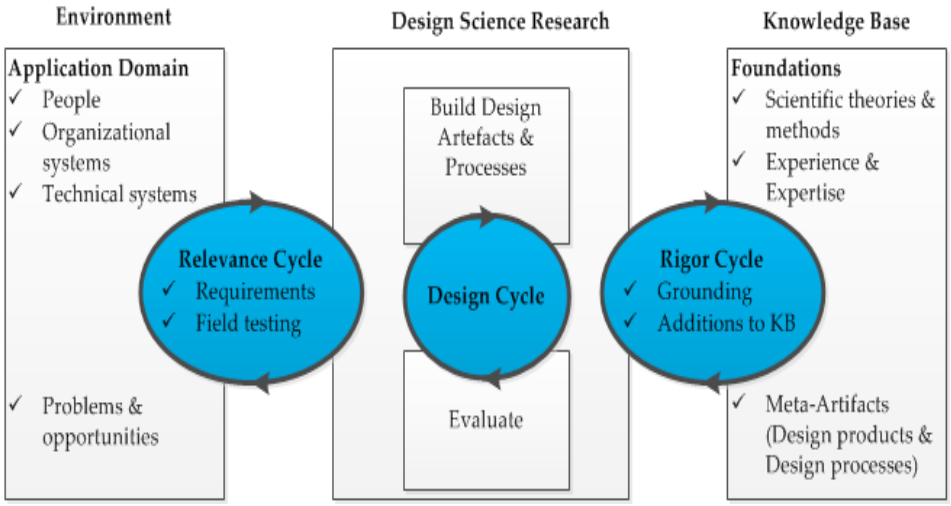
Aggregation of crowdsourced data, in order to arrive at answers, is a mandatory undertaking for every crowdsourcing project, and is an active topic of research (Vuurens, De Vries, & Eickhoff, 2011). In Hung, Tam, Tran, and Aberer (2013), aggregation models are categorised into either *non-iterative aggregation* or *iterative aggregation*. As the names suggests, non-iterative aggregation is done in one cycle, while iterative aggregation requires multiple cycles, where results of one cycle form input to the next. Examples of non-iterative aggregation models include *majority decision* (MD), where a simple majority is used to aggregate data and *honeypot* (HP), which filters out workers who are not competent, using questions whose answers are known (Lee, Caverlee, & Webb, 2010). Examples of iterative aggregation models include *expectation maximisation* (EM) and *supervised learning from multiple experts* (SLME).

3. Methodology: Design science research

The pragmatic philosophical world view was adopted for this research. This view assumes the world can be changed and scientific knowledge can be generated through the development of new interventions (Seyppel, 1953). Within the pragmatic view, we adopt the design science view, which is a problem solving view that aims to generate knowledge, through creating solutions that are relevant to addressing practical problems (Benbasat & Zmud, 1999). Within the design science view, the design science research (DSR) approach was adopted since our objective was to create a new artefact.

The DSR approach has its roots in engineering and other applied sciences and research is aimed at introducing enhanced designs/products to address identified theoretical and practical challenges. DSR's overarching principle is "exploring through creating" (Venable, 2006). Hevner (2007) summarised the DSR research into three cycles, consisting of the relevance cycle, design cycle and rigour cycle, as shown in Figure 1. Development of the artefact is situated in the middle of the problem domain and the knowledge domain.

Figure 1: Design science research cycles



Source*:* Hevner (2007)

The execution of DSR-type research is done through a specific, structured research process. Several closely related DSR research processes are presented in literature, for example (i) Peffers, Tuunanen, Rothenberger, and Chatterjee's (2007) six step process, consisting of problem identification, motivation, objectives of a solution, design and development, demonstration, evaluation and communication; and (ii) Offerman, Levina, Schönherr, and Bub's (2009) four step process, consisting of analysis, projection, synthesis and communication. This study adopted the approach developed by Vaishnavi and Kuechler (2004), consisting of awareness, suggestion, development, evaluation and conclusion stages, with circumscription at various stages. Creation of this model was justified by the need to find a cost effective means to identify organisms.

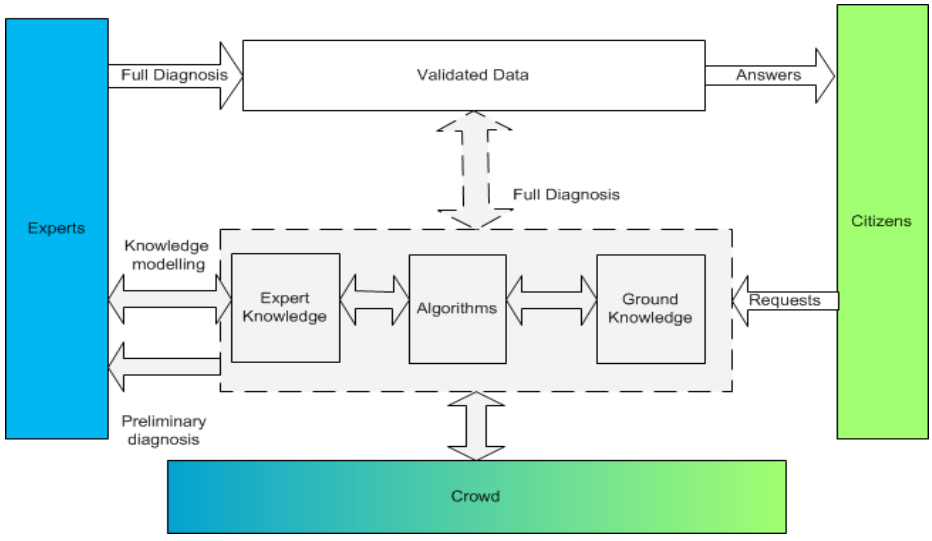
The development of the conceptual architecture was conducted through iterative steps that involved abstraction from the development of a crowdsourcing platform and referencing the relevant literature. The final architecture was refined through abstraction from the developed platform. The prototyping approach was used in application development (Canning, 1981). The Darwin core standard (Wieczorek et al., 2012) was used to guide the development of occurrence recording requirements. The majority decision (MD) model was used in the agregation of crowdsourced data (Kuncheva, Whitaker, Shipp, & Duin, 2003).

Based on the DSR knowledge contribution framework developed by Gregor and Hevner (2013), the contribution made in this study is an improvement to existing theory. The conceptual architecture is an improvement on the crowdsourcing work presented in Matheson (2014). Using the taxonomy of theory types in information systems research presented by Gregor (2006), the theory contributed in this article is a design and action type of theory, since it provides explicit prescription of a form of structure for construction and if acted upon (through software development) it leads to an artefact of a certain type (a system).

4. A conceptual architecture for citizen-expert knowledge exchange

A high-level model of the architecture shows the location of the various actors in the knowledge exchange. Citizens request biodiversity knowledge-based services and the crowd, with varying knowledge levels, is used to bridge the gap between citizens and experts as shown in Figure 2. Citizens may also participate in the crowd and the distinction here between citizens and the crowd is merely based on the distinctive roles where citizens are, for instance, the farmers who request services, whilst the crowd participates in the crowdsourcing aspect of the system and therefore has an alternative motivation. We propose an approach where neither crowd nor citizen is expected to provide full answers to requests, but rather the answers from crowd members are combined to answer the requests.

Figure 2: High-level knowledge exchange architecture between experts and citizens mediated by a crowd



In this approach, the crowd participants annotate ground knowledge with axioms from an ontology of expert knowledge. Using relevant algorithms, the annotations are analysed against the expert knowledge, allowing for provision of answers to requests. The outcome of the crowd activities is either full diagnosis, which forms part of the validated data, or preliminary diagnosis, which is marked for experts to provide full diagnosis. This approach provides participation opportunities for citizens with varying skills levels in knowledge exchange and utilisation tasks.

A detailed conceptual architecture for citizen-expert knowledge exchange, for species identification, is presented next. Nine key components of the architecture were identified, namely: (1) amateur recorders, (2) crowd, (3) experts, (4) unidentified records, (5) an ontology of expert organism identification knowledge, (6) crowd tags, (7) identification algorithms, (8) standards, and (9) species data.

One of the core objectives of the conceptual architecture is participation of online crowds in identifying amateur-recorded samples. The activities of crowds therefore surround the amateur records, which have not been identified scientifically. The interaction between the identified components is shown in Figure 3, and in Table 1 the components are described.

Figure 3: A conceptual architecture for ontology-driven organism identification using crowdsourcing techniques

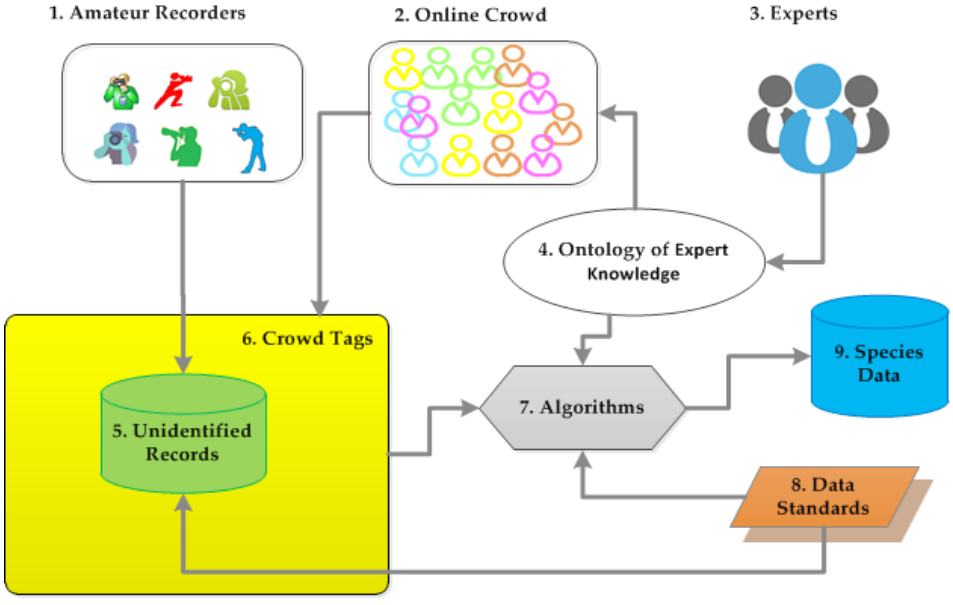


Table 1: Components of the conceptual architecture

Architecture component	Description
1. Amateur recorders	These are non-expert persons who record occurrences of organisms on online platforms, without the full scientific identification of the occurrence. The participants who make these recordings are motivated by various reasons, including seeking answers to questions regarding specific cases, as a recreational activity, as volunteers to a cause they consider important, as a source of income if the project remunerates participants, or out of interest to participate in solving certain problems.
2. Online crowd	This is a large number of people who have access to the Internet and have the ability and willingness to perform clearly defined online tasks, motivated by reasons such as fun, monetary compensation, social status, or contribution to the greater good of society. Every project should look into ways to motivate participation by the crowds.
3. Experts	Biodiversity domain experts with scientific knowledge about the target organisms.
4. Expert knowledge	This is an ontology of expert knowledge, specifically, the morphology and traits knowledge of the targeted class of organisms. The ontology is developed by ontology modelling specialists, in consultation with experts in the taxonomy of the targeted category of organisms. We recommend that the identification knowledge is modelled using the model presented in Gerber et al. (2014), which is of the form: Given an organism *O,* taxonomic grouping *tG*, a set of defined features *f1*……*fn* and object property hasDiagnosticFeature *hDF* the knowledge is modelled as follows: - tG = O ∩ (hDF f1) ∩ (hDF f2) ∩ ….. ∩ (hDF fn) Using this model makes it easy to get taxonomic groupings that have a set of features. The taxonomic groups are established by getting all the groups that have an intersection of all the selected set of features.
5. Unidentified records	This is a data store containing the recordings that have not been identified. Each occurrence record should consist of the time and place the organism was observed, a description in natural language, and images or videos (media files) of the sample.
6. Crowd tags	These are annotations made by the crowd on the different amateur records. The features for annotation are axioms from the ontology, or natural descriptions, depending on crowd tasks.
7. Algorithms	This is a collection of algorithms necessary for the identification of the samples. The data used by the algorithms are the crowdsourced tagged samples, the biodiversity standards, and the ontology of expert knowledge. See Appendix 1 for detailed description of the algorithms.
8. Standards	Recording biodiversity data requires adherence to certain standards. This ensures the data may be combined and analysed with datasets from other sources. The Darwin core standard is the relevant standard in this case, since this will ensure the datasets meet the attributes requirements of the standard (Wieczorek et al., 2012).
9. Species data	This is a data store of identification results from the crowd. The data are generated, after processing for identification results, by the identification algorithm. The data should be linked to identification requests, so that requesters can query identity status of their requests. The species data are also used as a basis to channel requests to relevant experts for confirmation and final identification.

5. Using the conceptual architecture

In this section, we present an example of the platform developed using the architecture. The platform was aimed at knowledge exchange between experts and farmers with respect to a case of a family of agricultural pests called tephritid fruit flies. These fruit flies are a major pest in the farming and horticulture industry in Kenya, affecting both fruits and vegetables. A key requirement for the control and management of the fruit flies is the identification of the species being targeted, as this guides the control methods and lures to apply (Billah, Mansell, De Meyer, & Goergen, 2007; Ekesi, De Meyer, Mohamed, Virgilio, & Borgemeister, 2016). This case was selected as part of ongoing efforts to aid remote, small-scale farmers to access expert knowledge on fruit flies and thus enable the possibility of immediate application.

In this section, a description of the key components of the final version of the platform is presented. Development of the platform was conducted using the prototyping approach, which involves quick development cycles in order to explore ideas (Canning, 1981; Yacoob, 1992). The Liferay framework, MySQL database and Java programming language were used in the development of the platform. We now present the instantiation of the architecture and implementation of key platform functional features.

Instantiation of the architecture

The components of the platform were implemented in line with the conceptual architecture as outlined in Table 2 below.

Table 2: Platform components as per the conceptual architecture

Architecture component	Implementation in platform
1. Amateur recorders	Fruit fly farmers who need identification services in order to decide on control and management measures to adopt.
2. Online crowd	Online volunteers recruited to register on the platform and perform identification tasks.
3. Experts	Expert scientists in fruit fly knowledge.
4. Expert knowledge	An ontology of fruit fly identification knowledge was modelled in earlier research and is documented in Kiptoo et al. (2016). The ontology consists of knowledge for identification of 30 species of fruit flies of most economic importance in Africa, documented in Billah et al (2007). The ontology was created in OWL using Protégé, and the ontology is incorporated into the platform with the related reasoning algorithms.
5. Unidentified records	Recorded samples in MySQL database. A user interface for recording requests is presented below.
6. Crowd tags	Tagging data generated through online crowds performing crowdsourcing task. The tagging data are recorded against each sample in the MySQL database. A crowd tagging task is presented below.
7. Algorithms	Identification of samples was done through the implementation of the identification algorithms described in Appendix 1. In this platform, the implementation of the identification algorithm is described below.

Architecture component	Implementation in platform
8. Standards	Darwin core standard is used in ensuring the data are recorded according to the biodiversity informatics data standards requirements.
9. Species data	Identification results stored in the MySQL database.

Platform functional features

In this section, the key functional features are described. Generating unidentified records was done through recording farmers' requests. Crowd tags on various samples were generated through requesting members of the crowd to tag each image with features. The identification process is presented below. Besides the functional features, the platform allows users to create a user profile and all the activities they perform are registered against their profile. Associating users' activities with their profiles enables users and administrators to keep track of the activities and successes of the participants. The platform also provides for linking users' profiles to their social media accounts, and therefore provides easy logins and easy ability to share their activities on social media.

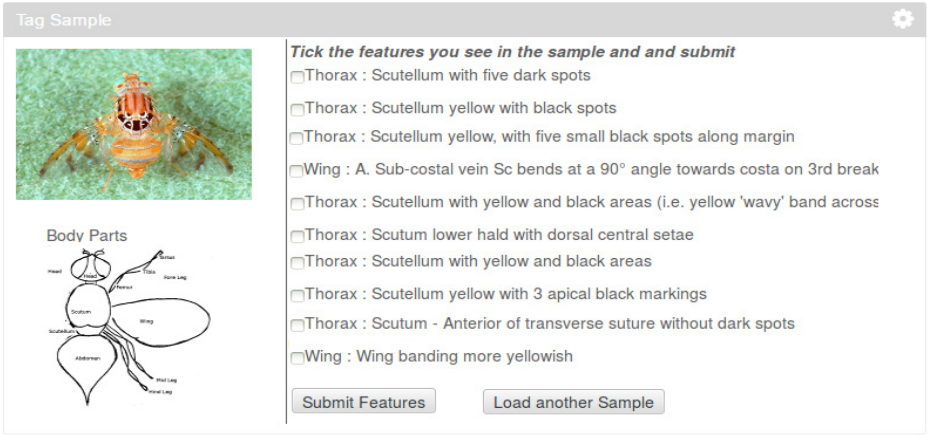
Record requests

The objective of this feature was to allow farmers to record an occurrence of fruit flies by providing minimal information about the occurrence, and by providing imagery. The interface for recording occurrences is a simple data capture form that provides the necessary functionalities to record a name chosen by the user, a simple description, the area where it was observed, date and time, and a maximum of 10 pictures per occurrence.

Tag samples

The guiding principle when the identification task was designed for crowdsourcing was to make the tasks as simple as possible, while still achieving the objective, which in this case was getting as many correct tags as possible on each image. The main task of identification was designed into micro-tasks, of tagging samples with a set of features from the ontology presented to the user. The task entailed tagging of features one can observe on an image presented to the user and clicking on a "submit" button to confirm, as shown in Figure 4 below. Upon submitting tags of one image, another image was loaded automatically with another set of features. The interface also provided the option to load another image, without tagging anything on the current image. Finally, since the names of body parts of the insects was not obvious to the crowd, a legend of the body parts was provided. For instance, for a feature stating "scutum yellow", the person could look up on the legend what the "scutum" is and be able to decide on such a feature. The legend aided in learning, thus improving the general knowledge of the crowd participants.

Figure 4: User interface (UI) for image annotation using identification features from the ontology of the identification knowledge



Note: *The UI has a magnifier incorporated to enable users to closely observe the images. A legend of different body parts is included so as to guide participants and therefore enable them to annotate, using features of most body parts, since part names are provided in the legend.*

Identification process

The identification process was designed to facilitate identification of the samples based on the aggregated tags made on each sample by the crowd. The process incorporated the services of a reasoner, who checked the aggregate tags made on each sample against the knowledge modelled in the ontology, in order to identify samples. Aggregation of crowdsourced data was done using the majority decision (MD) approach, which considered the number of votes per feature. We argue that the feature with the highest vote is likely to be present in the sample. The features were thus ranked from the one with the highest number of votes to the one with the least, and the resulting ordered feature list was used in the identification algorithm described in Appendix 1.

6. Evaluation experiment using the fruit fly platform

In order to assess the conceptual architecture and the ability of crowds to execute the identification activities, and ultimately to identify samples, we designed an experiment focused on the fruit fly. We now present the results of the experiment.

Experiment design

The objective of this experiment was to evaluate the viability of the conceptual architecture for organism identification through crowdsourced identification features of samples. The evaluation process was conducted using 25 images of samples that

had already been scientifically identified by experts. In the experiment, the samples were labelled as S1 to S25. The objective was to recruit participants to perform the crowdsourcing tasks and to evaluate the extent to which crowd identification is of comparable quality to expert identification.

Experiment results

A total of 75 volunteers were recruited and asked to register and execute the sample tagging tasks. No form of training was provided and participants were expected to learn and execute the tasks on their own. A total of 8,728 tags were made, of which 6,286 (72%) were correct, while 2,442 (28%) were incorrect, as shown in Figure 5. At the individual level, the highest scorer had 96.2% accuracy, and the lowest score was recorded as 13.8% accuracy. The individual performance was calculated based on a simple percentage of the number of correct tags out of the total number of tags. In Figure 6, the performance distribution of the crowd is shown. The chart shows the number of people who got an average score within the ranges. The performance distribution yields a near normal distribution curve.

Figure 5: Overall crowd performance in tagging samples

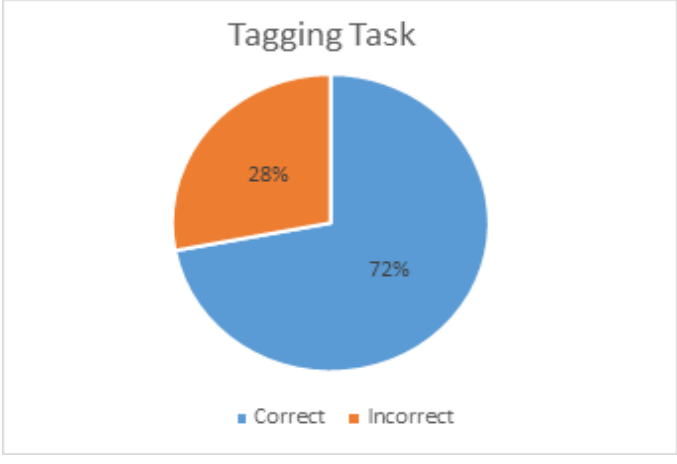
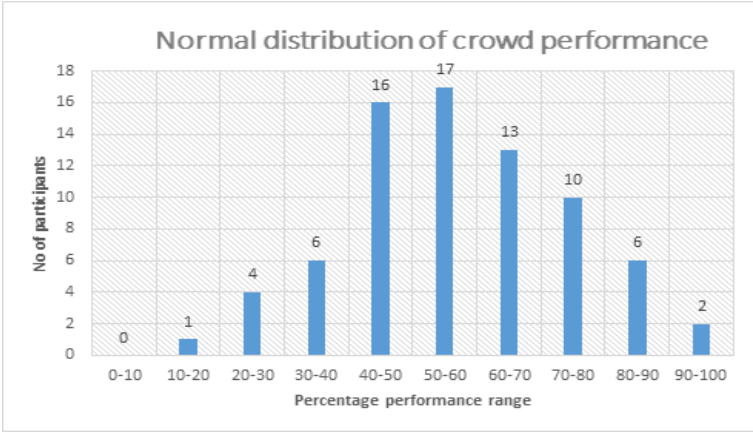


Figure 6: Crowd performance distribution: Number of participants who scored within the ranges



Finally, the level of identification of samples by the crowd was evaluated. Using the identification algorithm on the crowdsourced data, the various samples were identified. In Table 3 below, we present the identification results of four samples, one selected from each sub-family. The data for these samples are available as Appendix 2.

Table 3: Crowd identification results of four samples: S1, S5, S12, and S19

	Expert identification		Crowd identification	
Sample	**Sub-family**	**Species**	**Sub-family**	**Species**
S1	Ceratitis	Ceratitis Anonae Graham	Ceratitis	1 Ceratitis Anonae Graham 2 Ceratitis Colae Silvestri 3 Ceratitis Ditissima 4 Ceratitis Faciventris Bezzi 5 Ceratitis Punctata 6 Ceratitis Rosa Karsch
S5	Dacus	Dacus Vertebratus Bezzi	Dacus	1 Dacus Vertebratus Bezzi
S12	Bactocera	Bactocera Cucurbitae	Bactocera	1 Bactocera Cucurbitae
S19	Trihithrum	Trihithrum Nigerrimum	Trihithrum	1 Trihithrum Coffae Bezzi 2 Trihithrum Nigerrimum

These samples indicate that the crowd identification of samples up to the sub-family level matched that of experts, and was therefore correct for all samples. At the species level, the crowd was able to fully identify the organism, or suggest a small set of possible species in that sub-family. In sample S1, a set of six possible species was identified, and all belonged to same sub-family. Sample S5 and S12 were fully identified by the crowd. Sample S19 identified two possible species that also belonged to the same sub-family.

Limitations in the experiment

The images of the fruit flies used in the experiment were generated for other purposes and not for online feature identification, and therefore were often not clear enough for the purposes of this research. There was only one image available per sample, but in an ideal case, there would be several pictures from different angles, in order to capture all features. We believe that this would substantially improve the results.

7. Conclusion and future work

The objective of this research was to develop a conceptual architecture for citizen-expert knowledge exchange in the biodiversity domain. The architecture used crowdsourcing driven by an ontology of expert knowledge. Nine components of the architecture were discussed, namely: amateur recorders, crowd, experts, unidentified records, an ontology of expert organism identification knowledge, crowd tags, identification algorithms, standards, and species data. The research demonstrated that the architecture could facilitate system implementation and yield results comparable to those from expert identification.

This conceptual architecture may guide and enable creation of citizen-expert knowledge exchange applications, which could alleviate the taxonomic impediment, as well as allow access to expert knowledge by poor citizens. Such an architecture may also enable the implementation of systems that allow non-experts to participate in the sharing of biodiversity knowledge, thus creating comprehensive biodiversity knowledge systems.

From a theoretical point of view, this research has contributed to system architectures and models for collection and sorting of biodiversity data. In the architecture, we propose the use of crowdsourcing techniques at feature level, to identify samples recorded online. At the practical level, the architecture guides system developers who are interested in creating systems that utilise crowdsourcing for identification of samples recorded in amateur platforms.

This research used a single fruit fly case to evaluate the architecture, hence the architecture needs further evaluation, using cases of other organisms. More research is also needed to evaluate the other models for aggregating the crowd tags, to curb against spammers and cater for the varying quality of workers. Research into the maximum

number of tags needs to be done, so as to optimise the use of the crowd workers. Crowd motivation to participate in tagging samples online needs to be investigated and appropriate reward systems proposed.

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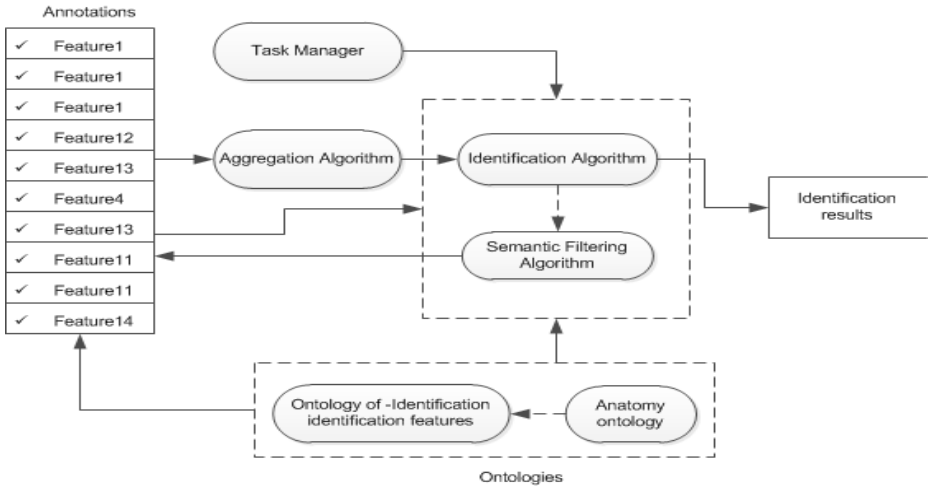
Appendix 1

The details of the algorithms component presented in Figure 2 are outlined here. Four algorithms were developed: task manager, tag aggregation algorithm, identification algorithm, and semantic filtering algorithm. The architecture of the interaction between the algorithms is shown in Figure 4 and the inputs include the crowd annotations and an ontology of identification knowledge.

1. *Task manager* manages the identification process of a sample to ensure the sample is subjected to relevant crowd tasks until fully identified. This algorithm coordinates when to utilise the other algorithms and ensures the samples are presented to the crowd members for tagging until they are identified as much as possible.
2. *Tag aggregation algorithm* ranks the features tagged by the crowd on each sample from the most likely feature to the least. For a start, the majority decision (MD) model (Kuncheva et al., 2003) can be used in this algorithm for the aggregation of the crowdsourced data. Any other model that is found to give better results can be adopted.

Figure 7: Identification workflow using four algorithms: Annotations aggregator, task manager, identification and semantic filtering



Note: *The algorithms use the annotations made by the crowd and an ontology of identification features as input for identification.*

3. *Identification algorithm* takes all the ordered tags made against a sample and, using the ontology of identification knowledge, processes them in order to assign scientific identification to samples. To identify a sample, the programme will incrementally check for species that match the features starting with the most popular until a final set is arrived at. The search for matching taxonomic groupings will stop when one species has been arrived at, or when the aggregate features from the crowd have all been used up. Once a sample is fully identified, it is recorded in the identification results data stores.
4. *Semantic filtering algorithm* is aimed at further separating a small set that has been arrived at through the identification algorithm. In some cases the identification algorithm can arrive at a set of possible species. This algorithm gets the non-common features of those species and presents to users for tagging the samples. This algorithm is invoked by the task manager when the identification results are more than one. This aids in further identification of the samples.

Identification using the algorithms begins with aggregation of crowd annotations by the aggregation algorithm. The aggregated data is then used by the identification algorithm and depending on identification results, the final results may be arrived at, or the semantic filtering algorithm may be used to request more tags on partially identified samples. The progression from one algorithm to another is managed by the task manager.

Appendix 2

Some of the data on the aggregate features tagged on each sample is presented here. The frequency column shows the number of times that feature was tagged. The highlighted features are what the algorithm used to retrieve a set of matching species.

Sample: S1	
Frequency	Feature
22	WingSubCostalVeinBendsat90DegreeAngleIDFeature
14	WingWithReticulateAppearanceIDFeature
13	ScutellumWithFiveBlackSpotsIDFeature
12	WingBasalcellsSpottedIDFeature
11	WingCostalBandcontinuoustoApicalendofWingIDFeature
11	ScutellumYellowWavyBandIDFeature
10	WingBasalcellsWithConsistentColorIDFeature
10	ScutellumYellowWithBlackSpotsIDFeature
10	WingBandBrownToBlackIDFeature
10	WingHasIsolatedPreApicalCrossBandIDFeature
9	OrbitalSetaeNotKiteLikeIDFeature
9	WingMedialVeinApexCoveredbyDiagonalColoredBandIDFeature
8	MidTibiaThickFeatheringLegIDFeature
8	ScutellumWithThreeLargeDarkSpotsIDFeature
7	MidLegThickFeatheringLegIDFeature
6	MidFemurThickFeatheringLegIDFeature
6	MidFemurFeatheringAlongAnteriorEdge

Sample : S5	
Frequency	Feature
21	WingSubCostalVeinBendsat90DegreeAngleIDFeature
16	WingHasNoIsolatedPreApicalCrossBandIDFeature
16	WingBasalcellsWithConsistentColorIDFeature
15	WaspLikeLookOveralIDFeature
14	ScutellumYellowandBrownIDFeature
8	AnatergiteAndKatatergiteBothWithYellowSpotIDFeature
7	FemoraWithYellowBasalandDarkerEndsLegIDFeature
7	BodyOrangeBrownDFeature
7	ScutellumYellowWithBlackSpotsIDFeature
7	WingWithReticulateAppearanceIDFeature
7	PostPronotalLobeYellowThoraxIDFeature
7	WingCostalBandcontinuoustoApicalendofWingIDFeature

7	WingMedialVeinApexCoveredbyDiagonalColoredBandIDFeature
7	MidFemurBasalYellowDarkApicalEndsLegIDFeature
7	AnatergiteAndKatatergiteBothWithYellowMarkingsIDFeature

Sample: S12	
Frequency	Feature
13	WingBasalcellsWithConsistentColorIDFeature
12	WingSubCostalVeinBendsat90DegreeAngleIDFeature
12	ScutellumYellowandBrownIDFeature
11	WingHasNoIsolatedPreApicalCrossBandIDFeature
11	WaspLikeLookOveralIDFeature
8	ScutumMedialORLateralStripesYellowOrangeThoraxIDFeature
7	HindFemurYellowatBaseLegIDFeature
7	MidFemurYellowatBaseLegIDFeature
7	MidTibiaDarkatBasalEndLegIDFeature
7	ForeTabiaDarkLegIDFeature
6	AnatergiteAndKatatergiteBothYellowIDFeature
6	ForeFemurBothSidesYellowLegIDFeature
5	WingWithPreApicalCrossBandandBroadApicalSpotIDFeature
5	ScutumWithLateralYellowStripesandDarkMarksonSidesIdFeature

Sample: S19	
Frequency	Feature
21	WingBasalcellsWithConsistentColorIDFeature
20	WingSubCostalVeinBendsat90DegreeAngleIDFeature
18	OveralSmallSizeFliesIDFeature
18	ScutellumMoreWhitishIDFeature
16	WingHasNoIsolatedPreApicalCrossBandIDFeature
16	WingWithoutReticulateAppearanceIDFeature
16	ScutellumBlackIDFeature
3	ScutellumYellowandBrownIDFeature
3	ScutellumWithThreeLargeDarkSpotsIDFeature

The Value of Knowledge Acquired via Online Social Capital: LinkedIn, a South African Perspective

Niresh Maharaj
Master of Business Leadership (MBL) Graduate, Graduate School of Business Leadership, University of South Africa (UNISA), Pretoria

Visvanathan Naicker
Professor, Office Management and Technology, Faculty of Business and Management Sciences, Cape Peninsula University of Technology, Cape Town

Abstract
This study investigated the value of a member's online social capital, in the social networking platform LinkedIn, in the following areas: member's subject matter proficiency, member's firm's problem solving ability, and member's firm's innovation process. The analytical framework used the concepts of social networks and online social networks (OSNs); social network ties; social capital and online social capital; knowledge and novel knowledge; communities of practice (CoPs); problem solving; and innovation. Quantitative methods were used, involving analysis of data collected from a sample of LinkedIn members residing in South Africa. It was apparent from the analysis that knowledge acquired on LinkedIn, relating to a member's subject matter proficiency, benefited the member's firm. It was also evident that this knowledge contributed to the firm's problem solving process. The data did not, however, confirm or refute the proposition that knowledge acquired by members on LinkedIn contributed to their firms' innovation. An overall observation from the data was that members did not perceive substantial value from the knowledge available on LinkedIn. The authors therefore recommend that greater initiative be taken by members and firms to adopt open networking approaches, using online social networks such as LinkedIn, starting with attitudinal and policy considerations on the part of firms.

Keywords
LinkedIn, social networks, social capital, online social capital, dense networks, weak ties, strong ties, structural holes, Web 2.0, online social networks (OSNs), subject matter proficiency, problem solving, novel knowledge, innovation, communities of practice (COPs)

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1. Introduction

The emergence of online social networks (OSNs) and Web 2.0 has significantly contributed to the use of the Internet, as evidenced by the substantial membership of popular OSNs such as LinkedIn, which has over 450 million members (LinkedIn, 2016). Members are able to construct an online identity and elicit voluntary connections with other members. They are also able to communicate with other members or broadcast information to multiple members within and beyond their network. LinkedIn is the context of this study and it is distinguished from the other online social networks because its members are predominantly professionals who seek economic and non-economic benefits from their online social capital (LinkedIn, 2016). The question that arises is: What are the implications of OSNs for firms? According to Zaglia, Waiguny, Abfalter and Müller (2015), social networks are a contributing factor in the growth and performance of firms, and if the OSN's provide a trusted environment, these networks will become more flexible and enduring by enhancing cooperation and building loyalty.

In the present extremely competitive business environment, firms are continuously seeking to gain a sustainable competitive advantage over their rivals (Grant, 2010). In order to achieve their strategic objectives, firms must deal with innumerable challenges to cultivate a sustainable competitive advantage. It may be argued that social capital resulting from participation in OSNs has a positive impact on social status and sociability and may therefore have a positive impact for firms arising from employee presence on OSNs. Hence, the objective for this study was to analyse whether the online social capital prevalent on LinkedIn can contribute to addressing three challenges. The first challenge is the development of the subject matter proficiency of the firm's human capital, since the core competence of a firm is determined by the strength of its human capital (Erasmus & Schenk, 2008). The second challenge is the firm's problem solving ability or its ability to transform its knowledge and intellectual property embedded within its human capital, both tacit and explicit, into viable solutions to address its operational business problems. Finally, the study evaluates the online social networks site LinkedIn as a source of knowledge that will foster innovation. Innovation is a concept that must co-exist with the need for change and it is widely believed that innovation enables firms to realise and maintain their competitive advantage in their business environments (Trott, 2012).

The research propositions for this study are accordingly stated as follows:

- **P_1:** Knowledge acquired on LinkedIn that is related to a member's subject matter proficiency benefits the member's firm.
- **P_2:** Knowledge acquired by a member on LinkedIn contributes to problem solving by the the member's firm.
- **P_3:** Knowledge acquired by a member on LinkedIn contributes to innovation by the member's firm.

OSNs such as LinkedIn will progressively become a more viable source of knowledge, in particular tacit knowledge, the reason being that, when establishing a knowledge sharing community and expert locating services in social media, they will support implicit knowledge sharing among individuals (Gordeyeva, 2010). This will enable firms to use their employees as conduits of knowledge from the broader environment to the firm and vice versa. Members of online social networks display a willingness to share their explicit and tacit knowledge with their online associates, despite weak ties between these members.

LinkedIn offers a potentially vast knowledge base of explicit and tacit knowledge that can be conveniently sourced online. Investigating the effectiveness of this knowledge source, within the scope and limitations of this research, may provide the foundations for further research into the potential of online social networks as viable alternatives to formalised classroom-based or non-Web 2.0-based online learning systems.

2. Literature review

Organisational knowledge is a complex construct that is composed of the collective explicit and tacit knowledge of its individuals, as well as an intangible component which remains within the organisation over time (Trott, 2012). Acquiring profound insight into the construct of the value of knowledge acquired via online social capital requires a detailed analysis of key foundational theories. Table 1 below summarises the theoretical framework.

Table 1: Summary of the concepts and artefacts for this study

Major concept or theory	Relevance to study
Social networks and online social networks	The focus of this study is the value of knowledge on LinkedIn, which is an online social network.
Social network ties	Members' ties are the primary source of knowledge on LinkedIn.
Social capital and online social capital	These are foundational concepts for this study of online social networks (OSNs) and knowledge exchange within OSNs.
Knowledge and novel knowledge	The first research objective of the study is to ascertain the value of knowledge acquired towards member proficiency.
Communities of practice and problem solving	The second research objective of the study is to ascertain the value of knowledge acquired towards problem solving.
Innovation	The third research objective of the study is to ascertain the value of knowledge acquired towards innovation.

Social networks

Networks can be defined as specific types of relationships connecting defined sets of people, objects or events (Knoke & Kuklinski, 1982, cited in Portes, 1998). When people are connected via these *specific types of relationships* the network is described as a social network. The defined sets of people, objects and events are often referred

to as nodes in a network. A key characteristic of the relationships in social networks emerges from the strength of the relationship or tie, i.e., a relationship can be categorised as a weak tie or a strong tie. Weak ties are usually bound by professional relationships or civic relationships with geographical proximity and have a low level of affection during exchanges (Olsen, 2008). People sharing weak ties usually interact less frequently through remote means. While geographic proximity in professional and civic relationships may lead to face-to-face interaction, the nature of the professional or civic relationships determines the frequency of interaction more than the emotive will of the related people (Olsen, 2008). Weak ties are prevalent in online social networks such as LinkedIn, where open networkers are prepared to connect to others, whom they have never met face-to-face, to acquire some form of benefit from the association. Connections between people who have met face-to-face in the past are also considered to be weak ties. Strong ties are characterised by emotional exchange, including support and advice underpinned by high levels of trust between members of the network possessing such ties (Duncan, 2012). Families and close friendships are forms of social networks that exhibit strong ties between their members. Interaction between people (members) with strong ties is usually face-to-face when there is geographical proximity, but also includes frequent remote communication such as online communication and telephonic communication in the absence of geographical proximity. Ostensibly, the corporate context is not devoid of strong ties. The existence of corporate social capital within firms emphasises the role of trust and shared objectives within these organisations (Dirks & Ferrin, 2001, cited in Benton, 2013).

The strong ties in the professional context are often present in closed or dense networks, which are social network structures where all members know each other. The dense ties cultivate communal duties, reciprocity, cohesiveness and enforcement of shared norms, and closed networks facilitate organisation, unity and common understanding (Benton, 2013). The aforementioned roles of such dense social networks have an inherent weakness, which is their inability to synthesise new or novel knowledge. This inherent weakness of dense networks has impelled the participation of many individuals, who are cognizant of this, towards open networking. The idea that more novel knowledge is exchanged between members with weak ties stems from the analysis that knowledge shared amongst closely tied members is mostly overlapping (Pénard & Poussing, 2010). Put differently, members of a strongly tied network tend to know what the other members within that network also know. Similarly, what has been referred to as "The Daily Me" can be a critical component of the *echo chamber effect*, a phenomenon exhibited in those Internet services where like-minded people listen only to those with whom they already agree (David, 2004).

The greater span of weak tied networks implies the prevalence of broader knowledge within such networks, as compared to smaller dense networks (Blanchard & Horan, 1998). The social network concept of structural holes, which refers to the

weaker connections between dense networks, presents attractive opportunities for weak tied members whose connections span these dense groups, since these members will have access to novel and heterogeneous knowledge across the groups (Widên-Wulff, 2007). Structural holes are prevalent on the online social network LinkedIn, with weak tied members each, in turn, being members of their own professional dense face-to-face networks. A thought-provoking and paradoxical view relating the concepts of social networking and knowledge transmission was posited by Anderson-Gough, Grey and Robson (2006, p. 236):

> it is possible to see how networking refers to a form of skill or expertise which is largely tacit and yet provides a kind of "social architecture" within and through which both professional knowledge and professional behaviour can be transmitted.

The notion is paradoxical since it is widely accepted in knowledge management theory that tacit knowledge is more difficult to disseminate than explicit knowledge; yet social networking, described as a skill which is "largely tacit", has provided a platform ("social architecture") for the transmission of such tacit professional knowledge. The following question now emerges: What motivates people to participate in and sustain a social network?

Social capital

Bourdieu defined social capital as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition" (Bourdieu, 1985a, p. 248). Bourdieu's definition of social capital included two distinct elements, namely the social relationship permitting access to the resources held by the respective acquaintances; and the extent and quality of the resources available (Bourdieu, 1985a; 1985b). Portes further analyses social capital by considering the impetus for the actors in the relationships, namely the donors and recipients. Recipients are ever willing to acquire access to useful resources that could result in economic or non-economic benefits, thus the impetus for recipients is rather logical (Portes, 1998). More complex though is the willingness of donors to provide resources without the guarantee of a return: Why would members of online social networks share tacit knowledge with their weak ties? The notion of norm of reciprocity offers an explanation for this behaviour. The norm of reciprocity holds that donors provide access to valuable resources to target recipients, with the expectation that these generous acts will be rewarded at a later stage by those recipients (Putnam, 1995, cited in Blanchard & Horan, 1998; Aguirre, 2011).

Two major benefits in the use of information and communication technologies (ICTs), such as OSNs, in enriching social capital are asynchronicity and customisability (Kobayashi, 2012). Asynchronicity refers to the asynchronous communication

between members of OSNs. Members can communicate conveniently at appropriate times of the day, when they are not otherwise occupied, via asynchronous messaging facilities on OSN sites. Synchronous communication on the other hand occurs in real-time and may not always be appropriate. Customisability refers to the ability of members to communicate in different patterns as required viz., one-to-one, one-to-many, and many-to-many. The value of one-to-one communication is readily understandable; while the utility of one-to-many and many-to-many forms of communication is that information and resources could reach a larger portion of the online social network. Apart from norms and networks, trust is also a vital component of social capital. Understanding online social capital requires an examination of the concept of online social networks, discussed below.

Online social networks

An OSN is a collection of individuals (members) connected together by a set of relations that are administered through a website (Claybaugh & Haseman, 2013). Claybaugh and Haseman further allude to the usefulness of social networking facilitated through the existence of virtual communities on the Internet; and remark on how the strength of connections or ties require fewer social assets when engaged via online means. On LinkedIn for example, weak tied relationships can be sustained through regular resource exchange with minimal face to face engagement. An obvious, but significant, difference between OSNs and traditional social networks is the lack of unifying physical activities in online social networks. On the OSN site LinkedIn, weak tied connections have little to no face to face interaction, since the relationship can be sustained and mediated online.

Knowledge acquisition and online social networks

Knowledge can be defined as a synthesis of experience, values, contextual information, expert understanding and insight that delivers a platform for assessing and incorporating new understandings and information (Tiwana, 2002). Tiwana further states that, although knowledge originates from people's cognition, it becomes embedded in an organisation's procedures, processes, ways of working, systems and norms. The quality of an organisation's knowledge is thus a central factor in determining its capability. Knowledge can be transformed into information, and OSNs are an abundant source of information, with information exchange happening constantly, driven by both organisational and individual motivations (Widên-Wulff, 2007).

Organisational motivations for knowledge sharing usually pertain to branding activities and creation of awareness to supplement competiveness. Individual motivations are more complex and include protective and enhancement motives (Nov, 2009). The protective motive notion posits that individuals will volunteer information to reduce their guilt associated with the perception of being more privileged than others. The enhancement motive notion, in contrast, posits that a person seeks to further enhance the perceived self-worth of a person by sharing information. Although people have

access to ample IT support and knowledge management databases, and the process of sourcing knowledge is embedded in the organisations way of working, they rely mainly on their social network within the organisation to acquire new information and create novel knowledge (Monti & Soda, 2014).

An OSN such as LinkedIn can potentially provide an extension of an individual's internal, organisational social network. OSNs such as LinkedIn become particularly useful for sourcing novel knowledge that may only be found beyond a dense network such as an organisation. LinkedIn can be seen as a social learning environment (SLE), which is an environment where individuals and groups can connect and co-create content, exchange knowledge and learn from one another to improve their personal and professional competence (Jones, Pole, Hole, & Williams, 2012). A key differentiator between SLEs and traditional organisational learning is that participants have control over their time, working space, actual presence, the activities they perform and the content they choose to consume.

The variety of content provided by the social network is also an advantage of SLEs over standard computer-based training, which usually offers fixed content that is pre-recorded. SLEs such as LinkedIn are ideal platforms for informal and borderless learning or knowledge acquisition (Jones et al., 2012). The first research objective for this study was to ascertain whether members of LinkedIn can enhance their subject matter proficiency through knowledge acquired from the OSN site.

Community of practice (CoP) and problem solving

A community of practice (CoP) is a group of individuals who have common interests and practices, or a common area of expertise, for example in their professional occupations, and who interconnect frequently to share knowledge regarding their interests (Chatti, 2009). CoPs are enabled on online platforms through the emergence of Web 2.0 technologies. Chatti (2009) defines Web 2.0 as the evolution of the World Wide Web towards a "read-write" platform where anyone can consume or produce knowledge and thereby contribute towards collaboration. Online social networks are ideal platforms for CoPs -- in particular LinkedIn, which is renowned for its features for professionals. The second research objective of this study was derived from the notion that the online social network LinkedIn is a suitable platform for a CoP: to ascertain whether knowledge acquired by members from the OSN site can facilitate problem solving in firms. The idea that new knowledge should be made accessible to dense networks cannot be overstated, as dense networks are susceptible to knowledge stagnation and this can impair firm competitiveness.

Novel knowledge and innovation

Members of an organisation benefit from external network connections because they gain access to novel knowledge, skills, and philosophies not available within their dense network (Wasko & Faraj, 2005). The acquisition of novel knowledge is facil-

itated by the absence of restraints of hierarchy and local rules. Novel knowledge is a more likely source of innovation than existing knowledge, since novel knowledge is more likely to inspire new thinking. Innovation should be seen as a process which involves the creation of products (or services) from inventions or new discoveries and the use of novel ways of doing things (Trott, 2012). The third research objective of this study, which is derived from the notion that OSNs are a viable source of novel knowledge, was to ascertain whether a member of LinkedIn can utilise knowledge acquired from the OSN site to facilitate innovation in the member's firm.

3. Quantitative survey design

The research methodology employed in this study is quantitative in nature and involves the analysis of data collected from a sample of LinkedIn members residing in South Africa. The data were collected by means of a structured online survey, which was also published to the researcher's first level connections on LinkedIn. The questions in the survey were designed to gauge the respondents' perceptions in relation to the three research objectives. Figure 1 below provides the overall process used for data collection. Data collection was conducted online using the SurveyMonkey tool.

Figure 1: Overall data collection process

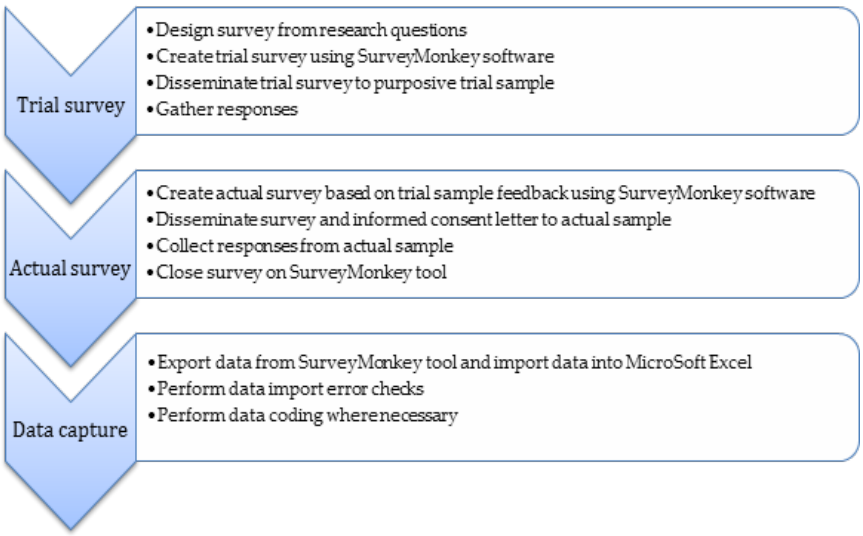

Table 2 lists the variables used in the survey and associated scale type. The survey was purposely designed to be completed promptly and contained variables that were readily known to the respondents. The intent was to increase survey response rate and reduce abandon rates to achieve the maximum sample size possible from the target sample.

Table 2: Variables used for structured survey

Variable	Scale of measurement
Country of residence	Nominal
Gender	Nominal
Age	Ratio
Highest level of education completed	Nominal
Work experience	Ratio
Number of LinkedIn connections	Ratio
Time spent on LinkedIn	Ratio
Knowledge and proficiency	Ordinal
Knowledge and problem solving	Ordinal
Knowledge and innovation	Ordinal

Country of residence was included to clearly demarcate the South African residents for the analysis. The gender of the members of the sample was recorded in order to compare the gender profile of LinkedIn users with the profile of other sources. Age class intervals were selected, in order of youngest to oldest, to demarcate scholars, university students and professionals at different stages of their careers. The highest level of education completed by the respondents provided an indication of their formal education status. LinkedIn is associated with working professionals who have had some form of formal education. The researcher's intent was to substantiate this association to some extent by describing the samples' levels of education obtained. The LinkedIn usage profile of the sample was captured in two variables, namely "number of LinkedIn connections" and "time spent on LinkedIn".

These variables provide an indication of the extent to which the respondents use LinkedIn. Typically, members with more LinkedIn connections use the online social networks more frequently and are probably longer tenured members. Members who spend more time on the OSNs are considered to be heavier users. The respondents' number of LinkedIn connections was recorded to provide an indication of how many first level connections they have. The value of knowledge acquired on LinkedIn towards a member's subject matter proficiency, towards problem solving, and towards innovation, were recorded in three Likert scale formats. All questions in these formats required one of five possible responses (never, rarely, sometimes, often, or very often) based on the respondent's perception of knowledge gained in relation to these three areas.

Two non-probability methods of sampling were used, namely a combination of convenience and multiplicity sampling (Diamantopoulos & Schlegelmilch, 2000). The researcher's first level connections were accessible on the LinkedIn site via a broadcast and LinkedIn's internal messaging facility. All potential participants were also requested to forward the survey to their first level connections. The target response

sample was 50 (N ≥ 50) respondents to enable meaningful cross-tabulation for analysis. The use of the non-probability sampling methods meant that, in theory, the research findings are not generalisable to the universe (N= 3million). However, it is debateable whether human beings' perceptions are generalisable in either case, namely in non-probability samples or probability samples (Leedy & Ormrod, 2010). The researcher felt that a coherent representation for this study is a significant sample (N ≥ 50) that includes a range for gender, age, education and work experience diversity.

The anonymous nature of the survey, as well as the design of the Likert scales, served to strengthen the authenticity of the respondents' answers. These factors could also have contributed to minimising social desirability bias, where respondents would be inclined to depict themselves in a more positive light. Likert scale items were presented as questions to minimise acquiescence bias (the inclination to agree with statements presented).

With respect to limitations, the perceptions of firms regarding the research objectives were not considered for this study. The reason for not pursuing this approach was the practical consideration of correlating the findings for firms with the findings for respondents. The assumption made by the researcher was that the respondents' perceptions represented their firms' perceptions to a sufficient extent. The researcher saw it as prudent to use a Likert scale to capture the respondents' perceptions on knowledge they have acquired on LinkedIn. This meant that the data captured on the variables linked to the research objectives could only be measured in ordinal scales. The researcher was thus limited to non-parametric tests on these variables during the analysis, given the sample size achieved.

4. Research findings and analysis

Fifty-eight (58) responses were received in total and 55 of the respondents indicated that they resided in South Africa (N=55). The sample included 12 females and 43 males. Twenty-two of the respondents, or 40%, were in the age group 30-39, while 18, or 33%, of the respondents were in the age group 40-49. This is consistent with the view that LinkedIn members are generally individuals with work experience. The perception that LinkedIn users are primarily professionals was substantiated by the finding that 91% of the respondents had completed formal education above high school. Additionally, 93% had more than five years' work experience.

LinkedIn usage profile of sample

An equal number of respondents, 14 (26%) respectively, had either "0-99" or "500 or more" connections. Almost half of the sample i.e., 27 (49%), spent less than one hour per week on LinkedIn, while a substantial portion. i.e., 23 (42%) spent between one and three hours per week on the site. Thus the LinkedIn usage of the sample was generally moderate.

Contribution of knowledge acquired on LinkedIn to work proficiency

The Likert scale data were converted into the composite score depicted in Table 3.

Table 3: Frequency distribution for knowledge and subject matter proficiency

Score	Absolute frequency	Relative frequency	Cumulative absolute frequency	Cumulative relative frequency
tending to never (0 - 0.25)	2	3.64%	2	3.64%
rarely to never (0.5)	2	3.64%	4	7.27%
tending to rarely (0.75 - 1.25)	12	21.82%	16	29.09%
rarely to sometimes (1.5)	6	10.91%	22	40.00%
tending to sometimes (1.75 - 2.25)	14	25.45%	36	65.45%
sometimes to often (2.5)	7	12.73%	43	78.18%
tending to often (2.75 - 3.25)	7	12.73%	50	90.91%
often to very often (3.5)	1	1.82%	51	92.73%
tending to very often (3.75 - 4)	4	7.27%	55	100.00%
Totals	55	100.00%		

Given that the cumulative relative frequency at "rarely to sometimes (1.5)" was 40%, it is apparent that 60% of the respondents perceived some kind of value from the knowledge acquired from their LinkedIn connections towards their proficiency at work. This substantiates proposition one (P_1) of this study: Knowledge related to a member's subject matter proficiency that is acquired on LinkedIn benefits the member's firm.

Table 4 below shows the cross-tabulation (absolute and relative frequencies (%)) for "number of LinkedIn connections" and "knowledge and subject matter proficiency".

Table 4: Cross-tabulation: Knowledge and subject matter proficiency and number of LinkedIn connections

Number of LinkedIn connections	Hardly perceived value		Perceived value	
0-99	8	14.55%	6	10.91%
100-199	3	5.45%	7	12.73%
200-299	4	7.27%	3	5.45%
300-399	2	3.64%	2	3.64%
400-499	3	5.45%	3	5.45%
500 or more	2	3.64%	12	21.82%

It is evident from the shaded areas in Table 4 that the largest groups of respondents in the categories "hardly perceived value" (8, or 14.55%) and "perceived value" (12,

or 21.82%) belonged to the lowest and highest "number of LinkedIn connections" categories respectively ("0-99" and "500 or more"). This suggests a positive association between "knowledge and subject matter proficiency" and "number of LinkedIn connections".

Contribution of knowledge on LinkedIn to work problem solving

The "knowledge and problem solving" variable was converted to a composite score depicted in Table 5 below.

Table 5: Frequency distribution for knowledge and problem solving

Score	Absolute frequency	Relative frequency	Cumulative absolute frequency	Cumulative relative frequency
tending to never (0 - 0.33)	8	14.55%	8	14.55%
tending to rarely (0.67 - 1.33)	16	29.09%	24	43.64%
tending to sometimes (1.67 - 2.33)	19	34.55%	43	78.18%
tending to often (2.67 - 3.33)	9	16.36%	52	94.55%
tending to very often (3.67 - 4)	3	5.45%	55	100.00%
Totals	55	100.00%		

Given that the cumulative relative frequency at "tending to rarely (0.67 – 1.33)" was 43.64%, it is apparent that 56.36% of the respondents perceived some kind of value from the knowledge acquired from their LinkedIn connections towards their problem solving at work. This substantiates proposition two (P_2) of this study: Knowledge acquired by members on LinkedIn contributes to their firms' problem solving.

LinkedIn usage and problem solving

Table 6 below shows the cross-tabulation (absolute and relative frequencies) for "number of connections" and "knowledge and problem solving".

Table 6: Cross-tabulation of knowledge and problem solving and number of LinkedIn connections

Number of LinkedIn connections	Hardly perceived value		Perceived value	
0-99	7	12.73%	7	12.73%
100-199	4	7.27%	6	10.91%
200-299	4	7.27%	3	5.45%
300-399	2	3.64%	2	3.64%
400-499	4	7.27%	2	3.64%
500 or more	3	5.45%	11	20.00%

It is evident from the shaded areas in Table 6 that the largest groups of respondents, in the categories "hardly perceived value" (7, or 12.73%) and "perceived value" (11,

or 20%), belonged to the lowest and highest "number of LinkedIn connections" categories respectively ("0-99" and "500 or more"). This suggests a positive association between "knowledge and problem solving" and "number of LinkedIn connections". The authors postulate that the more LinkedIn connections a member has, the more likely the member is able to be able to source knowledge that can contribute to problem solving.

Contribution of knowledge on LinkedIn to innovation

The "knowledge and innovation" variable was converted to a composite score depicted in Table 7.

Table 7: Frequency distribution for knowledge and innovation

Score	Absolute frequency	Relative frequency	Cumulative absolute frequency	Cumulative relative frequency
tending to never (0 - 0.25)	9	16.36%	9	16.36%
rarely to never (0.5)	2	3.64%	11	20.00%
tending to rarely (0.75 - 1.25)	13	23.64%	24	43.64%
rarely to sometimes (1.5)	4	7.27%	28	50.91%
tending to sometimes (1.75 - 2.25)	13	23.64%	41	74.55%
sometimes too often (2.5)	2	3.64%	43	78.18%
tending to often (2.75 - 3.25)	10	18.18%	53	96.36%
often to very often (3.5)	0	0.00%	53	96.36%
tending to very often (3.75 - 4)	2	3.64%	55	100.00%
Totals	55	100.00%		

Given that the cumulative relative frequency at "rarely to sometimes (1.5)" was 50.91%, it is apparent that 49.09% of the respondents perceived some kind of value from the knowledge acquired from their LinkedIn connections towards their firms' knowledge and innovation. This finding does not invalidate proposition three (P_3) of this study: Knowledge acquired by members on LinkedIn contributes to their firm's innovation. However there is no overwhelming evidence to confirm it either.

LinkedIn usage and innovation

Table 8 below shows the cross-tabulation (absolute and relative frequencies (%)) for "number of LinkedIn connections" and "knowledge and innovation".

Table 8: Cross-tabulation of knowledge and innovation and number of LinkedIn connections

Number of LinkedIn connections	Hardly perceived value		Perceived value	
0-99	10	18.18%	4	7.27%
100-199	4	7.27%	6	10.91%
200-299	4	7.27%	3	5.45%
300-399	3	5.45%	1	1.82%
400-499	3	5.45%	3	5.45%
500 or more	4	7.27%	10	18.18%

It is evident from the shaded areas in Table 8 that the largest groups of respondents, in the categories "hardly perceived value" (10, or 18.18%) and "perceived value" (10, or 18.18%), belonged to lowest and highest "number of LinkedIn connections" categories respectively ("0-99" and "500 or more"). This suggests a positive association between "knowledge and innovation" and "number of LinkedIn connections".

5. Analytical discussion

The purpose of this study was to investigate the value of knowledge acquired from OSNs from the perspective of members of LinkedIn who reside and work in South Africa. The value of knowledge is as infinite a construct as knowledge itself. The study thus focused on the value of knowledge in three key areas: contribution to the member's firm's subject matter proficiency; contribution to the member's firm's problem solving ability; contribution to the member's firm's knowledge and innovation process.

Analytical point: The value of knowledge to member subject matter proficiency

The results of the analysis demonstrate that P_1 is plausible. The cumulative frequency of the variable "knowledge and subject matter proficiency" shows that a majority of members perceived that their subject matter proficiency was promoted by using the knowledge they acquire on LinkedIn, with benefit to the firm. The plausible association between the LinkedIn usage variables and "knowledge and subject matter proficiency" suggests that P_1 becomes a stronger proposition with a larger number of LinkedIn connections.

Analytical point: The value of knowledge to problem solving

The results of the analysis demonstrate that P_2 is plausible. The cumulative frequency of the variable "knowledge and problem solving" shows that a majority of members perceived that the knowledge they acquired on LinkedIn tended to supplement their firm's problem solving capability. The plausible association between the LinkedIn usage variables and "knowledge and problem solving" suggests that P_2 becomes a stronger proposition with more substantial LinkedIn usage.

Analytical point: The value of knowledge to innovation

The results of the analysis demonstrate that P_3 cannot be considered plausible; however, it cannot be rejected either. The cumulative frequency of the variable "knowledge and innovation" shows that members were somewhat divided in their opinion of the contribution of knowledge from LinkedIn to their firms' innovation. The plausible association between the LinkedIn usage variables and "knowledge and innovation", however, suggests that P_3 may become a stronger proposition with more substantial LinkedIn usage.

The value of knowledge acquired via online social capital

The more people engage with each other, the greater the opportunity for harnessing mutual trust and the greater the opportunity for the norm of reciprocity to operate to induce resource exchange (Aguirre, 2011). Similarly, in online social networks, regular interaction with associates through weak ties builds trust under the norm of reciprocity, particularly interaction that involves the exchange of resources, for example tacit novel knowledge. Tacit novel knowledge can be disseminated and consumed in a brief message exchange via an OSN platform, while OSN platforms remove the barrier of geographical distance and are a discrete means for associates with weak ties to communicate. One can thus speak of the prevalence of online social capital on OSN site.

Donors and recipients of resources are members who are connected to each other on the OSN site, where donors and recipients could have weak or strong ties. The nature of online social capital is based on the same fundamental aspect that characterises traditional social capital, namely the norm of reciprocity, underpinned by trust. A means towards understanding the effectiveness of the resources gained by recipients is to examine the measurements, indicators and dimensions of social capital. Three apparent measurements of social capital for individuals are the size of the social network, the density of the social network, and the frequency of interaction with the social network (Pénard & Poussing, 2010). Traditional social capital theory has been developed largely from the study of traditional social networks.

The benefits of online social capital for organisations, gained via their members, include augmenting and sustaining intellectual capital, increasing creativity and cross-fertilisation, improving the decision-making process using epistemic communities, reducing training costs, identifying customer needs and new product opportunities, and reducing travel costs and addressing problems promptly (Howard, 2010). Motivated by the norm of reciprocity, members from different organisations may share novel knowledge amongst each other. Intellectual capital that is acquired could be sustained when members codify the knowledge in their organisations' knowledge management systems. Creativity and cross-fertilisation are increased through participation in online forums and consumption of broadcasts that are available to members of OSNs.

The knowledge gained is dispersed into the receiving member's organisation when the member utilises the knowledge in the organisation's activities. The existence of online forums within OSNs also provides an accessible source of knowledge that can be used by the organisation in its decision making process. With the knowledge available online and virtually free, and the onus of human capital development being shared by the individual as well as the organisation, organisations may need to invest in the development of their employees in non-traditional ways.

6. Conclusions and recommendations

It can be argued, based on the findings and analytical discussion, that members are not benefiting optimally from the potential knowledge available from their networks in the areas discussed in this study. This could be due, in part, to lethargy in adoption, and, in part, to the attitudes and policies of firms towards open innovation and networking on OSNs.

Adoption of open networking by firms

Firms should realise that traditional closed innovation is not a sustainable strategy (Bigliardi, Ivo Dormio & Galati, 2012; Trott, 2012; Van de Vrande, De Jong, Vanhaverbeke & De Rochemont, 2009). Usage of OSNs such as LinkedIn should be encouraged to help address the issues discussed in this study, namely human capital development, problem solving, and innovation. Firms can embrace OSNs and open networking for knowledge acquisition by formulating policies for their promotion.

Firms' attitudes and policies on OSNs such as LinkedIn

Firms need to formulate and foster official stances and governance on the use of OSNs at work. These measures will remove any ambiguity on the ethical use of OSNs in the context of the firm. More importantly, from the firm's perspective, policies and orientation with respect to OSNs could provide guidance to staff on how to best use OSNs for the purposes of contributing towards achieving a sustainable competitive advantage.

Member initiative

Members of LinkedIn in South Africa may perceive LinkedIn as predominantly a conduit to possibly secure new employment opportunities, because LinkedIn professes to be a hub for recruiting professionals and because recruitment agencies and many firms use OSNs to find and contact potential job candidates. The onus is on members to realise that LinkedIn offers a wealth of potential knowledge via its connections and groups. There are many features of LinkedIn which facilitate knowledge exchange and these are available at low cost, e.g., professional galleries with work examples, photos and video, and the use of slide-share; the targeted search function with advanced people-finder capabilities; and the ability to join groups, which make members and firms more visible.

LinkedIn and its Web 2.0 capability

OSNs such as LinkedIn should look towards developing their site capabilities to further promote Web 2.0 features and to promote knowledge sharing for open innovation. While this process would require some innovation and investment in research and development, the potential benefits could be rewarding for both the OSNs and their members.

Concluding remarks

This study is significant in that it investigated the implications of OSNs, a novel though rapidly proliferating concept, in relation to knowledge acquisition, which is an ageless and infinite concept. The findings are especially significant for firms who are now considering open innovation and networking as means for gaining sustainable competitive advantage. It can be expected that we will see substantial investment into further research on the convergence of the concepts of online social networks, knowledge and novel knowledge, open innovation, and open networking.

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Development Informatics Research and the Challenges in Representing the Voice of Developing Country Researchers: A South African View

Judy van Biljon
SARChI Chair in Information and Communication Technology for Development; Professor, School of Computing, University of South Africa (UNISA), Pretoria

Abstract
Indigenous or local researchers from developing countries have not made a leading contribution to development informatics (DI) or information and communication technologies for development (ICT4D) research. This is noteworthy since these researchers should be in a prominent position to contribute to the discourse, where context knowledge is regarded as vital. Furthermore, a dependence on foreign scholarly direction can create a gap between research and reality in a way that affects the success of ICT programmes in African countries. Extant literature highlights this problem, but most studies stop short of considering the causes and proposing how to amplify the voice of developing country researchers. This paper documents the ICT4D/DI research discourse that took place during four seminal academic events in South Africa during the period 2012 to 2015. Those discussions are presented and analysed here to contribute to the wider discourse on ICT research and practice in developing countries, with the aim of enhancing the research contribution of developing countries. An interpretivist, involved researcher analysis of the workshop reports is conducted to gain an improved understanding of the South African ICT4D/DI researcher's challenges to proportional participation. While this study takes a South African perspective, many of the findings could apply to researchers in other developing countries.

Keywords
development informatics, ICT4D, research participation, challenges

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1. Introduction

Information and communication technologies for development (ICT4D) "is the name given to a range of activity which considers how electronic technologies can be used towards socio-economic development of developing communities worldwide" (Donner & Toyama, 2009, p. 1). The technology needs to be designed to operate in a complex social, political, economic, and cultural context and therefore it is necessary to consider the multi-perspective approach of the ICT4D domain (Thapa & Sæbø, 2014). Wilson (2002) maintains that the commonly assumed model of ICTs and development is grounded in assumptions of technological determinism, which allow the complex political factors influencing poverty and inequality at local, national and international levels to go largely unquestioned. This model is based on the construction of what counts as legitimate or valuable information and knowledge, the developmental aims of the programmes and the particular models of progress focused on catching-up to industrial country ideals.

Sen's theory of human capability criticised the emphasis on the economic criteria of advancement as the primary or sole means of measuring human wellbeing and proposed the capabilities approach towards increasing human opportunities, capabilities and freedoms (Sen, 1999). Sen's capabilities theory has been criticised for obscuring or neglecting three key realities, namely the constitutive nature of human interdependency, the problematic nature of the public realm, and the exploitative nature of capitalism (Dean, 2009). However, the prominence of Sen's theory in development informatics (DI), as operationalised by Kleine (2010), is an influence to be recognised in evaluating developmental outcomes (Hatakka & Lagsten, 2012).

Against the ongoing debate of what development is, this article focuses on the definition of developing, emerging and developed countries as characterised by Roztocki and Weistroffer (2011). South Africa, a country with one of the highest Gini coefficients in the world in terms of both income and wealth, i.e. the greatest dispersion between the rich and the poor in terms of income and wealth distribution (Bosch, Rossouw, Claassens, & Du Plessis, 2010), exhibits characteristics of both developing and emerging economies. Given the difficulties in distinguishing between developing and emerging economies, the term *developing country* will be used to include both developing and emerging economies for the purpose of this article.

Given the broad scope of DI, which spans a number of diverse disciplines, and the multi-, inter- and trans-disciplinary nature of the field, it is inevitable that there would be divides and tensions in the quest to understand how technology interacts with global development (Burrell & Toyama, 2009). Therefore research into the use of information and communication technologies (ICT) for development inhabits a contested space, characterised by varying philosophies, aspirations, realities and priorities (Van Biljon & Alexander, 2015). One of those divides relates to the use of the terminology relating to ICT and development, where the term ICT4D has been

associated with a techno-centric approach and DI with a socio-centric approach (Heeks, 2007; Zheng & Heeks, 2008). In terms of presenting a South African view, it is necessary to consider both the DI and ICT4D communities in South Africa and therefore the terms *development informatics* (DI), *ICT-for-development* (ICT4D) and *ICTD* (*ICT-and-development*) are used interchangeably in this paper, except when explicitly distinguishing between the terms.

Community informatics (CI) is a research domain related to DI (Stillman & Linger, 2009). According to Gurstein (2004), CI is the application of ICT to enable and empower community processes. Stillman and Linger (2009) maintain that CI has a dual focus: first, the conduct of research about the relationship between the design of ICTs and local communities, and second, the implementation of ICT projects in local communities. The purpose of this article is to investigate the research publication challenges researchers in DI experience. This population of researchers includes ICT4D and CI researchers, as researchers often work at multi-, inter- and trans-disciplinary levels. A fairly substantial body of work has been generated to conceptualise the DI landscape and to set research priorities and approaches in the field. Examples of these endeavours are summarised and presented in Table 1, towards highlighting the trends in country participation.

Table 1: Comparing studies on trends in country participation

Citation	Period	Scope	Trends and challenges identified since 2006
Walsham & Sahay, 2006	2000-2004	Review of papers from 13 journals and two conference proceedings on information systems in developing countries.	A lack of article contributions originating from the indigenous or local researchers in developing countries.
Gitau, Plantinga & Diga, 2010)	1990-2009	A quantitative survey of Thomson Reuters Web of Science database to identify academic conferences and journal publications authored or co-authored by African scholars.	The African contribution to international ICTD research and scholarship was estimated to be in the region of 1% to 9%.
Gomez, 2013	2000-2010	Content analysis of 948 papers using two conference series and five journals.	Comparing research focus between countries, most papers focused on India.
Williams, Lenstra, Ahmed & Liu, 2013	No date range	Analysed the first author affiliations by region of 563 CI empirical studies.	Most papers were contributed by authors from North America, followed by Asia, Europe, Africa, Oceania and Latin America. The prominent countries were the US (40%) and UK (10%), followed by India (10%), Australia (5%), Canada (4%) and South Africa (3%).

Thapa & Sæbø, 2014	No date range	Analysed 80 ICT4D papers, selected with a Web of Science keyword search, limited to highly cited papers and authors.	They concluded that research in the ICT4D area was mainly conducted in sub-Saharan African countries, India, and Latin America. The contributions of authors from developing countries were not specified, but of the 10 papers identified for further analysis, only four had a developing country researcher as the first author.
Naudé, 2015	2000-2013	Analysed 378 articles published in the *Electronic Journal of Information Systems in Developing Countries (EJISDC)*	Of the seven world regions, Africa had the strongest author presence with 179 authors (21.88%), followed by Asia with 173 authors (21.15%), North America with 159 authors (19.44%), Europe with 157 authors (19.19%), Oceania with 92 authors (11.25%), Latin America and the Caribbean with 39 authors (4.77%), and the Middle East with the lowest author contribution at 19 authors (2.32%).
Ghosh, Mudavanhu & Belle, 2015	2011-2014	Analysed papers published by the International Development Informatics Association (IDIA)*	South Africa was identified as the country with the highest number of researchers presenting at IDIA conferences. Sadly, papers from other African countries were largely missing. In 2014, for example, only one paper was from another African country, Namibia. In 2013, there were no papers from other African countries.
* Notably the IDIA was established specifically to provide a platform for information exchange between global South-based ICT4D researchers with the hope of providing a more critical and context-aware strand of ICT4D research (Ghosh, Mudavanhu, & Belle, 2015). The aim is made explicit as being to escape the dominant viewpoints and biases that may be present in the ICT4D research initiated by researchers in developed countries.			

The findings from the studies presented in Table 1 support the notion that researchers from developing countries are under-represented in terms of publication output. The exception is the output generated by the conferences of the IDIA, which was initiated with the aim of presenting research from developing countries and mostly features South African authors (Ghosh, Mudavanhu & Belle, 2015). Naudé's (2015) findings seem to indicate an increase in the research contribution from developing and emerging countries, especially from Africa. However, it has to be noted that Naudé's findings were based on only one journal. Furthermore, North America and Europe combined still contributed 40% of the total publications in the *EJISDC* journal analysed. Bidwell (2016) contends that the visibility of African human-computer interaction research and practice, in Africa and internationally, is challenged, because the practices of technology production, education and research tend to reproduce meanings that associate the continent with absence. The methodologies employed in the papers mentioned in Table 1 consisted mostly of a rigorous literature review of the conference and/or journal publications that have a high proportion of ICT4D relevant papers. Though helpful in quantifying the phenomenon, the studies mentioned (except for Gitau et al., 2010) do not provide insight into the reasons for the less than proportional contribution made to DI research by developing country researchers. This study takes a qualitative approach, by analysing workshop outcomes from four South African workshops focused on connecting DI researchers and promoting DI research. The aim is to provide some insight into the challenges South African researchers face in the dissemination of their research.

2. Conceptual divides in the ICT4D literature

Donner and Toyama (2009) identified the *digital divide* as the most powerful popular concept in the ICT4D area. The *digital divide consensus* has long become an inadequate guide for researchers and policymakers alike (Galperin, 2010) and it has since been associated with the first wave of ICT for development, namely modernisation and transfer (Heeks, 2014). However the DI field is still characterised by divides and therefore the known divides are proposed as a way of structuring the challenges that could impact researchers' participation in publishing and disseminating DI research. The *technical-social*, *research-action* and *developed-developing* divides in community informatics research as identified by De Cindio (2015) are discussed here as a literary frame of reference for a thematic analysis of the ICT4D workshop reports presented in this study.

1. The *technical-social* divide relates to the difference between researchers with a concern for artefact-type problems and design, and those researchers more concerned with social and social-technical problem-solving (Walsham, 2013). Zheng and Heeks (2008) identify a hard-soft tension, i.e., deterministic, standardised approaches versus softer approaches that investigate institutional and social complexity and informal and contingent circumstances, including cultural differences.
2. The *research-action* divide contrasts the focus on academic value (publications, citations and other academic requirements) with the potential benefits that effective implementation could bring to a community (De Cindio, 2015). From a community informatics perspective, the lack of a tight connection between research and action is a source of problems impacting both the practical relevance (projects not having been implemented and tested) and the theoretical contribution (field projects undertaken without a scientifically rigorous background), which applies to DI as well. Heeks (2007; 2014) and Walsham (2013) note a tendency to prioritise action over knowledge, with few authors contributing to theory building. Steyn (2015) argues for ICT4D research going beyond the comparison of technicalities and artefacts, to address the foundational assumptions and concepts in the field.
3. The *developed-developing* divide provides challenges on many levels. At a philosophical level, the divide goes to the very definition of what *development* is (Merritt, 2012; Wilson, 2002). The fact that much of the research (including the technology used) is planned and funded from developed countries, specifically the global North, while the implementation and evaluation are done in developing countries, can influence the perceptions of what topics are relevant, which may then impact on publication opportunities and success (Gitau et al., 2010). Another example is the publication of future DI research priorities by researchers from developed countries, as in the *Future Priorities for Development Informatics Research from the Post-2015 Development Agenda* by Heeks (2014). Due to global crises, the differences are somehow shrinking, enhancing the possibility to learn, each from the other side (De Cindio, 2015). Furthermore, the current crisis in

funding and political support to the development sector accentuates the urgency of improving internal collaboration and information sharing processes (Müller, 2014).

The *technical-social, research-action* and *developed-developing* divides have implications for ICT4D research in terms of prioritising items on the international research agenda, which influence funding and publication opportunities, for example priorities as disseminated through influential publications such as the *Digital Dividends* report (World Bank, 2016).

3. Methodology

As is evident from the introductory problem-setting, there is less than proportional participation from indigenous or local researchers from developing countries in the publication of DI research. This motivated the meta-research question for this study namely:

- What is the state of development informatics in South Africa in terms of challenges to research participation?

Given the aim of understanding the situation and access to the primary "data" captured at ICT4D workshops in South Africa, the broad investigative goal was translated into the following research question:

- What challenges to South African DI research have been identified in the so-called "ICT4D workshops" conducted from 2012 to 2015?

The reporting on the workshops is done from the perspective of a researcher (the author) in the Gauteng province, who was tasked to establish a new ICT4D research group, without having been connected to any existing group and who was interested in understanding the South African ICT4D landscape. The approach has limitations, but it is considered a useful point of departure in presenting the challenges experienced by researchers in the South African DI landscape since 2012. Given the aim of understanding the research challenges, an interpretive methodology was considered appropriate. The author was a participant in all the workshops and involved in organising some of them. Geertz's (1973, p. 9) interpretive view is particularly appropriate to describing the data collected from the workshops, as he states: "What we call our data are really our own constructions of other people's constructions of what they and their compatriots are up to".

The researcher's stance resonates with the interpretive stance of the involved researcher actively trying to improve the situation (Walsham, 2006). A thematic analysis was considered, but given the differences in the formats of the data, that was problematic. Instead the workshop report review was organised around specific themes (see Table 2) and interrogated for providing insights into the three research gaps (the *technical-social*, *research-action* and *developed-developing*) as discussed in the

literature review.

Reports from the following events in 2012, 2013, 2014 and 2015 were considered for analysis:

- In 2012, the first workshop of the ICT4D workshop series was hosted at the University of South Africa (UNISA). The programme consisted of invited presentations, followed by a panel discussion on ICT4D research agendas. The speakers were prominent ICT4D champions from the International Development Informatics Association (IDIA) (based in South Africa), the Council for Scientific and Industrial Research (CSIR) and UNISA.
- In 2013, a workshop was conducted at the CSIR (Pretoria) with speakers from IDIA (South African and Australian) and doctoral students who presented their work. No data were captured in terms of outcomes or objectives so this event was excluded from the analysis.
- In 2014, there was a concerted effort to unite the researchers from the northern part of South Africa with those of the southern parts, and two widely advertised workshops were conducted. The first was at the 2014 conference of the South African Institute of Computer Scientists and Information Technologists (SAICSIT 2014) in Pretoria and the second was at the 2014 International Development Informatics Association Conference (IDIA 2014) in Port Elizabeth. At SAICSIT 2014, the groups represented at the meeting were given the opportunity to present their research focus areas. This was followed by a discussion on collaboration initiatives. At IDIA 2014, the findings from the SAICSIT 2014 workshop were discussed together with an invitation for new research groups or initiatives to be added. Research groups who had not presented their research foci at SAICSIT 2014 were requested to do so, but only one group, namely Monash University, was added. It is important to note that the two workshops were held at different geographic locations (one in the north, one in the south) in South Africa, and this provided the opportunity for researchers and practitioners from both northern and southern research localities to be involved.
- In 2015, it was agreed that the SAICSIT events would be organised alternately by the groups in the south and the north of the country, hence the 2015 event at SAICSIT was hosted by the University of Cape Town in Stellenbosch. The format was to have two invited speakers, followed by a group discussion on challenges and initiatives towards promoting ICT4D research in South Africa and Africa.
- The events in 2012, 2014 and 2015 were selected for analysis and evaluation, based on their relevance to shaping the ICT4D landscape in South Africa and the availability of the workshop reports, but it is noted that there were other ICT4D events during this time. The workshop reports analysed in this article were selected because they are in the public domain and were made available to the attendees for scrutiny and feedback. However, interpreting events towards

extracting insights is open to subjectivity and therefore it has to be recognised as an involved researcher's abstraction of the reports provided. Furthermore, the information about research agendas and thematic areas has to be viewed in terms of the date of the event, as research agendas may change over time. Grounded theory, described by Urquhart, Lehmann and Myers (2009) as a qualitative research method that seeks to develop theory grounded in data systematically gathered and analysed, may be an appropriate methodology for theorising the research participation of developing country researchers in an extended future study.

4. Overview of the results

The workshops are tabulated in Table 2 to allow some overview and comparison between the events on selected attributes. This is followed by a more detailed discussion of each workshop. The ICT4D workshop reports were sent out to the attendees for review and comments and updated according to the feedback provided. The workshop reports summarising the outcomes are available from Van Biljon (2016).

Table 2: Comparative summary of the ICT4D workshops

	2012 UNISA	2014 SAICSIT	2014 IDIA	2015 SAICSIT
Attendance	Attended by 66 people but many of those were not involved in ICT4D research.	Attended by 36 people, all of whom were involved with ICT4D as researchers.	Attended by 24 people, all of whom were involved with ICT4D as researchers, practitioners or both.	Attended by 32 people all of whom were involved with ICT4D as researchers, practitioners or both.
Minimum number of South African institutions involved	4	9	11	14
Audience participation	Questions to panel.	Attendees were grouped according to their research institutions and each group presented the focus of its group.	The audience responded to a summary of the activities at SAICSIT 2014.	Attendees selected their groups based on the most relevant ICT4D challenge. Each group presented its response to the challenge.

Outcome	Consensus on research agenda. General focus on readiness and availability.	Consensus on collaboration initiatives. Developments and differentiation made it difficult to identify a common research agenda. The focus was on identifying research areas for collaboration. General focus on uptake and impact.	Consensus on collaboration initiatives. The ideas of more special issues on ICT4D, and an open, South African knowledge repository, were discussed.	Goals related to: structure and dissemination; research priority areas; engagement and collaboration; curriculum and teaching.
Challenges	Connecting research groups. Identifying champions. The need for sustainable long-term networks of participants. The need to make a better world with ICT4D.	Publication opportunities. Collaboration opportunities. Institutional factors.	Publication opportunities. Knowledge sharing via lists. Political and language bias.	Publication opportunities. Knowledge sharing via lists or websites. Funding. Difference between information systems and computer science research interests.

2012 UNISA (organised by UNISA)

The event held on 8 February 2012 at UNISA was titled "Towards a Research Agenda in ICT4D", with participation from the CSIR, Monash University, the University of Cape Town, and the University of Pretoria.

The strategic development focus as advocated by Thompson and Walsham (2010) was emphasised by a group of panellists and the discourse could be placed in the fourth wave of DI research development, namely design and impact (Heeks, 2014). In summary, the following perceived needs within the South African ICT4D research community were listed: the need for "bridges", the need for "champions", the need for long-term engagement, the need for sustainable long-term networks of participants, and the need to make a real difference.

The following research directions were identified towards establishing an ICT4D agenda: monitoring and evaluation of projects in the ICT4D field; theories, models and practical examples; moving from understanding the artefact to understanding ICT enabled work practices in meeting development; scalability, sustainability, impact assessment and learning from IS failures; and socio-technical perspectives on ICT4D. The gurus (ICT4D champions) listed were Chrisanthi Avgerou, Richards Heeks, Mikko Korpela, Ojelanki Ngwenyama, Sundeep Sahay, Kentaro Toyama, John Traxler, Tim Unwin and Geoff Walsham.

2014 SAICSIT (organised by the University of Pretoria, UNISA and the University of Cape Town)

Each participating research institution was presented with the opportunity to explain its focus and the thematic areas of involvement and requested to include a diagram of the presentation. Figure 1 provides an overview of the main institutions represented and the thematic areas covered, including the CSIR Meraka Institute, Nelson Mandela Metropolitan University (NMMU), Rhodes University, University of Cape Town (UCT), UNISA, the University of Pretoria (UP), the University of the Western Cape (UWC) and the University of the Witwatersrand (Wits). One user experience researcher from the Western Cape Province government was present, but since no other government departments or practitioners were present this is not included in Figure 1. The data are based on the input of the attendees, which may present an incomplete picture of the activities at these institutions. However, it remains useful in getting an overview of the fields covered.

Figure 1: Main institutions represented and the thematic areas (based on SAICSIT 2014 event)

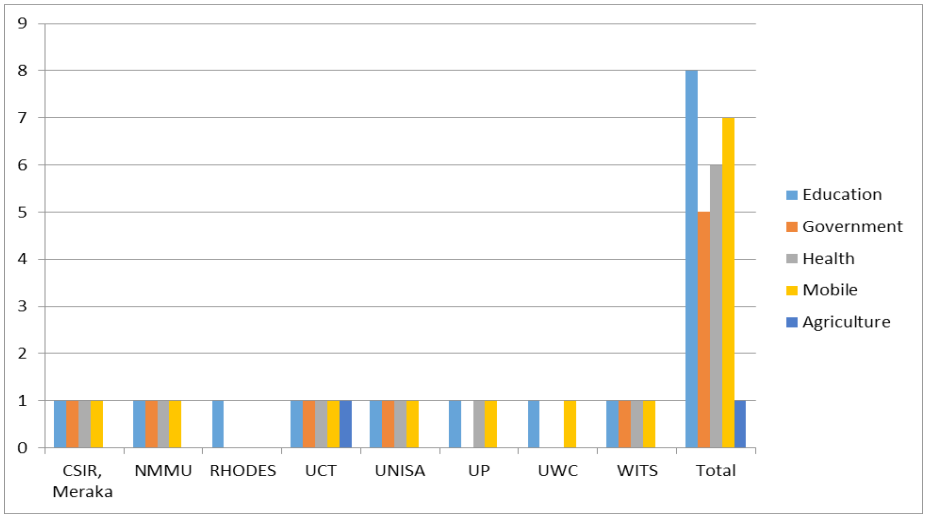

Table 3 presents the research fields in which the researchers were located, together with cross-cutting thematic areas. The participants were requested to select one of two fields, information systems or computer science, which obscures the fact that they may also have been working in other fields. Despite the limitation on the scope of the data (only one workshop), the depiction is considered useful as a starting point in plotting the DI landscape, particularly as the participant responses were aggregated to the institutional level, revealing some detail of the institutional research focus.

Table 3: Research focus of South African institutions involved in ICT4D (based on SAICSIT 2014 event)

Affiliation	Field *	Additional fields (if mentioned)
CSIR Meraka	IS, CS	Monitoring and evaluation
NMMU	IS, CS	Not stated
Rhodes	IS, CS	Critical theory
UCT	CS, IS	Heritage, computations, linguistics, computational, neuro-science
UNISA	CS, IS	Knowledge management, culture, humanities, entrepreneur-ship, creative industries
UP	IS	Creativity, monitoring and evaluation
UWC	CS	Not stated
Wits	IS	Smart cities
* IS = information aystems; CS = computer science		

2014 IDIA (organised by UNISA, UP and UCT)

The organisers presented feedback on the SAICSIT 2014 event earlier that year (see details in Figure 1 and Table 2), and collaboration initiatives were discussed. The initiatives included proposing a special issue with an African focus in a high impact ICT4D journal, a Google Group ICT4D-4ALL to be used for distributing further communication, and development of a knowledge repository on South African ICT4D research.

2015 SAICSIT (organised by UCT)

The topics identified for the group discussions included structure and dissemination, research priority areas, engagement and collaboration, and curriculum and teaching. The ideas for promoting ICT4D research in South Africa and the collaboration initiatives identified by each group were presented and recorded. The initiatives were recorded, with the idea that the individuals assigned under the various topics would work towards the goals listed, especially those related to community building and the hosting of events in future years.

In summary, the format and purpose of each of the four workshops was different, as the understanding of the field and the cohesion among the researchers evolved. Some of the challenges noted pertained to the connection between researchers individually and also between groups; the need to identify champions; the need to do meaningful research towards making a better world with ICT; publication, collaboration and funding opportunities; and, finally, the perceived paradigmatic divide between the technical and socio-technical aspects. Although the discussions were not focused on research contributions alone, all the challenges mentioned could influence the research participation and impact on South African DI researchers. A limitation is that the respondents were mostly from universities, so other stakeholders were not

equally represented. In mitigation, the researchers at universities are an important grouping when considering publication challenges.

5. Discussion

The challenges identified during the workshops are now structured according to the three divides (De Cindio, 2015) discussed in the literature review.

Technical-social divide

The interdisciplinary nature of the field, and more specifically the socio-technical gap (Zheng & Heeks, 2008) identified in literature, were confirmed as contributing to the challenge of collaborating. Notably, researchers from the socio-technical research stream (mostly researchers with a background in information systems) prefer the term DI, while researchers from computer science favour the term ICT4D. The request was made for dedicated streams on artefact design and development, in conferences like the IDIA conference. However, an analysis of IDIA publications in terms of research areas (Ghosh et al., 2015) has shown that 43% of the papers published in the period 2011 to 2014 were in fact on artefact design and implementation. This highlights the need for more awareness and knowledge of research and dissemination opportunities in the research community.

When considering the past and future of DI research in terms of the four development waves, Heeks (2014) mentions the evolution from a techno-centric agenda to a more socio-centric agenda. Accordingly, it is necessary to consider that the terms technical and social may be complementary rather than opposing. While the computer science stream may be more focused on the artefact and design science perspective, this does not exclude investigation of the socio-cultural aspects using multi-, inter- or trans-disciplinary approaches.

The role of terminology in complicating ICT4D research and dissemination should not be under-estimated. Merrit (2012) notes the disagreement about the term ICT4D, specifically the "4D" (or "for development"), where both "for" and "development" are troublesome words for reflective practitioners and researchers, potentially presenting both opportunities and challenges in the field. The term *digital development*, rather than DI or ICT4D, was used in the 2016 World Development Report titled *Digital Dividends* (World Bank, 2016). Heeks (2016) makes an interesting comparison, linking the term digital development to "Development 2.0" models and the term ICT4D to "Development 1.0" models, and argues that digital development could possibly be termed *ICT4D 3.0.* The latter approach provides a way of capturing the evolution without "losing" the value inherent in the ICT4D brand, as also recognised in the Heeks (2015) narrative and understood by non-academic stakeholders. An in-depth discussion of the terms is beyond the scope of this article, but while acknowledging that specialisation and refinement of terms are part of the academic discourse, it is also necessary to consider the adverse effects of continual rebranding

in a context with diverse stakeholders, including researchers, practitioners, funding agencies, NGOs, governments and industry.

In the interests of global development and for the progress of the field, it is imperative that research efforts are complementary and cumulative, rather than siloed or oppositional (Donner & Toyama, 2009). Shared terminology is one of the fundamental constructs enabling interdisciplinary dialogue and therefore the overall cost-benefit of continually changing terminology should be considered. This should not be confused with the intention to eliminate alternative assumptions or theoretical perspectives, as warned against by Avgerou (2010), as this pertains only to the notion that introducing new terms should be done mindful of the branding aspect, i.e., the inherent value of a generally known and accepted term in connecting diverse stakeholders. Based on the literature and the discussions in the workshops, it can be concluded that the technical and social are both essential aspects of the DI discourse. Albeit driven by researchers with different backgrounds and skills, the focus should be on promoting an understanding of the common interests, while recognising the value of disciplinary, subject-specific research in both the technical and the social aspects of DI. An implementation example is to have conferences with a keynote or other plenary sessions that explicitly reach out to non-subject specialists (Walsham, 2013).

Research-action divide

The need to make a positive and meaningful difference, as called for at the 2012 UNISA Workshop, relates to the research-action divide (De Cindio, 2015) mentioned earlier and to the tension between the desirability of interdisciplinary work and the realities of current social structures of academic prestige and reward (Walsham, 2013). It resonates with the unifying vision of "making a better world with ICTs" (Walsham, 2012) and implies the need for outsider-researchers involved in ICT4D research and practice in Africa to honestly question their own values, attitudes, motives and understanding of the development reality (Krauss & Turpin, 2013). This resonates with the advocacy of Gitau et al. (2010) and Bidwell (2016) for a local interpretation and publication of African narratives. Gitau et al. (2010) identified publishing culture, institutional factors, information access, political and language bias and, finally, lack of conference attendance, as issues that influence ICT4D research dissemination by Africans. The findings from the workshop analysis confirm that all of these remain relevant barriers, with lack of funding impacting institutional factors, conference attendance and information access.

Vivier, Wentzel and Sanchez (2015) argue that an effective communication interface between government and citizens can strengthen government responsiveness and deepen citizen engagement. While such communication and information exchange takes many formats, given the various platforms and technologies available, the development of an ICT4D knowledge repository, as called for at the IDIA 2014

conference, could prove useful in connecting stakeholders across the divides.

Developed-developing divide

Global academic literature remains dominated by northern hemisphere research and developed world models that do not always take into account the specific socio-political environments of the developing regions (Alperin, 2015; Neylon, Willmers & King, 2013) and the challenges faced by researchers from developing and emerging economies. Citation metrics, like any other socially constructed information and knowledge artefact, can reflect unequal distributions of power and privilege and therefore the factors influencing bibliometric and altimetric data should be analysed when considering the research perspective on meaningful and equal partnerships with community, civil society and NGOs (Van Biljon, Naudé, & Lotriet, 2016). As cautioned by Gitau et al. (2010), a gap between researcher and reality can affect the success of ICT programmes in African countries, but also reflects a more serious dependence by Africa on foreign scholarly direction. From observation of Figure 1, it can be seen that *education* was the best represented research area for the group of SAICSIT 2014 workshop attendees, while education is not rated a top priority in terms of internationally under-researched DI areas (Heeks, 2014). Ghosh et al. (2015) highlight the same finding in the IDIA (2011-2014) analysis and explain that, in terms of the challenges South Africa faces in developing human capacity under conditions of severe resource and skill constraints, this is an example of local researchers addressing local challenges, even though that topic is not prioritised on the international publication agenda.

During the 2012 workshop, the need for local ICT4D champions was identified. The gurus identified were not from South Africa, Africa or even developing countries. Renken and Heeks (2014) describe an ICT4D champion as a person with a strategic vision towards ensuring *results*, who engages with stakeholders towards promoting *ideas*, rallying support and finding consensus in building *relationships* and who actively identifies and mobilises the *resources* required to advance the project. They distinguish between the attributes of *importance* and *influence* when considering ICT4D champions. While local ICT4D champions are well situated to understand the importance of research problems and needs, the influence of international ICT4D champions resident outside the developing world has to be recognised as a force that could shape research agendas and the dissemination of research outputs constructively.

Developed country researchers may have a more nuanced understanding of the formal academic publication and dissemination context, since most of the high impact journals are managed from developed countries and often by editors from developed countries. Considering the top 10 empirical case studies on rural and remote communities selected for analysis in a literature review on the link between ICT and development in the context of developing countries (Thapa & Sæbø, 2014), it is interesting to note

that only four of those involve collaborations between a developing and developed country researcher. Bidwell (2016) warns against collaborations where the African counterparts are limited to collecting data because publishing time constraints do not allow for the development of more equitable partnerships. Based on the literature and the findings from the workshops presented, it is concluded that international collaboration should be recommended, on condition that the collaboration involves the ongoing exchange of ideas, bilateral knowledge transfer, and equitable sharing in the research knowledge commodification.

Alternative thinking about DI research

Interdisciplinary research fields present challenges to professional librarians and scholars who aim to characterise and delineate subject areas (Less, 2008). A study on country trends and scholarly collaboration in the ICT4D research community (Naudé, 2015) identified disciplinary differences and research domains (e.g. , ICT4D) as factors that may limit visibility, exposure, readership and citations. Altmetrics (alternative citation metrics) measure scholarly performance of individual articles, based on engagement of scholars and the public with research articles in online and social media environments (Lin & Fenner, 2013). Altmetric measures are steadily gaining ground in the global political environment, where research institutions are under increasing pressure to provide evidence of not only scholarly, but also societal impact of the research (Bornmann, 2014; Neylon et al., 2013). The increased use of altmetrics should be considered towards overcoming some of the institutional and financial barriers to disseminating and promoting research output.

In a study on South African ICT4D websites, dedicated ICT4D or DI websites could be found for only five of the 23 public universities (Van Biljon, Pottas, Lehong, & Platz, 2016), while nine of those were involved in the SAICSIT 2014 workshop. The lack of online presence is undoubtedly a barrier to discoverability and participation. Finding research output and dissemination opportunities, with regard to publication, funding and collaboration, were rated more challenging by researchers from some South African institutions than others. Therefore it seems that the dissemination of information about publication, funding and collaboration opportunities could play a role in improving the situation.

The establishment of ICT4D/DI events, where representatives of the universities and research organisations meet annually at two main South African research conferences, is a positive development towards community building. Practitioner and government involvement is less evident, but some practitioners and government representatives attended the 2014 and 2015 events and thus initiatives to improve communication and research awareness between the sectors is recommended. The latter is important in managing the research-action divide and improving impact beyond academic publications. The IDIA conference has become an important venue for connecting South African researchers and amplifying their voice, but involving

researchers from other African countries is clearly a priority.

6. Conclusion

A number of studies on country participation and regional trends, published in the past decade, support the fact that indigenous or local researchers in developing countries, including South Africa, have not contributed proportionally to DI research publication output. This article documents the ICT4D/DI discourse that took place during four academic events in South Africa over the period 2012 to 2015. The workshop documentation and analysis is presented as a point of departure in reflecting on the South African DI discourse and how the discussions at those events, including the challenges mentioned and outcomes proposed, can be used to inform future developments and strategic decisions.

The challenges identified in contributing to the research literature relate, inter alia, to the research-action divide, and time and resource constraints, which are not unique to the discipline. Other challenges, like the conceptual gaps identified, may be inherent to the interdisciplinary nature of the field, thereby limiting the publication opportunities to a specific stream within the interdisciplinary field. Disciplinary, institutional and financial barriers to disseminating and accessing publications impact bibliometric measures of ICT4D research, but altmetrics show potential for overcoming some of the institutional and financial barriers. The actionable challenges relate to a consideration of the impact of continual rebranding of the field in terms of the terminology used, information and dissemination opportunities, and the underplayed role of local research champions.

Dissimilar levels of access to available publication, collaboration and funding opportunities can be mitigated by online knowledge sharing and thus the proposed initiative of developing an open knowledge repository should be investigated. The establishment of dedicated ICT4D/DI events is a positive development towards community building, but more efforts are needed to facilitate practitioner involvement. The promotion of local ICT4D champions and sustainable, long-term research collaboration between developed and developing country researchers have also been mentioned as initiatives to amplify the voice of South African DI researchers. Future research is needed to monitor and evaluate the impact of the current initiatives towards improving the publication contribution of indigenous or local South African DI researchers and to extend the study to include other African countries.

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Symbolic Narratives and the Role of Meaning: Encountering Technology in South African Primary Education

Izak van Zyl
Associate Professor, Transdisciplinary Studies, Research, Innovation and Partnerships, Cape Peninsula University of Technology, Cape Town

Amalia Sabiescu
Research Associate, Institute for Media and Creative Industries, Loughborough University London

Abstract
This article draws on the results of a long-term, design-based research study with South African primary school teachers to discuss the role of subjectively assigned meanings and symbolisms of technology, as key factors affecting the adoption, appropriation and use of educational technology in urban poor and under-resourced environments. The paper examines how teachers' engagements with technology are framed, conditioned, and embedded in multi-levelled "technology encounters". These encounters give rise to meaningful representations of technology that ultimately transform both the teaching and learning process, and culminate in the emergence of "symbolic narratives": complex assemblages of symbolisms, meanings and interpretations that arise through and therefore come to influence further technology engagements. We argue that a closer examination of teachers' symbolic narratives can shed light on the motivations that underpin the appropriation, integration -- or conversely, rejection -- of educational technology in urban poor and under-resourced environments.

Keywords
educational informatics, information and communication technology (ICT), technology encounters, symbolic narrative, meaningful representations of technology

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1. Introduction: Exploring the meaning of technology in primary education

The long-term, design-based research study with South African primary school teachers, which generated the data on which this article is based, commenced in 2008 with the aim of examining the conditions through which teachers in so-called "disadvantaged" primary schools applied information and communication technologies (ICTs) in practice. The research problem concerned the complex impacts of ICT for education in resource-restricted environments, from the perspective of teachers. The fieldwork experiences in South Africa led to the realisation that ICT is far from a tangible reality in many local schools, especially in terms of the availability of resources and infrastructure; access to information and educational opportunities; and a holistic understanding of the enabling values of technology. However, considering the recognition that ICTs can transform education and the increasing need for ICT-enhanced teacher development (Enigda, 2011; UNESCO, 2011), the drive towards technology in South African primary education has continued. The focus on educators in disadvantaged communities is of academic interest, because of the promise that ICT holds for such environments (Bladergroen et al., 2012). But it is precisely in those environments where stakeholders have the most difficulty in assimilating technologies. In going beyond the "promised" utility that ICTs pose, an exploration of meaningful engagement is where advances are needed in the field.

The research was conducted on the Khanya Project, though not formally affiliated to the project or its members. Khanya was conceived in 2001 by the Western Cape provincial government as a technology access initiative, whose goal was to distribute computer facilities to all primary schools in the Western Cape by the end of 2011. Experiences from the study reported here revealed many opportunities and challenges in terms of the technology-for-education model propagated by Khanya. The findings reveal that the underlying causes for the accomplishments and failures of the Khanya model are best articulated by adopting a perspective that goes beyond an instrumentalist and pragmatic approach to the investigation of technology usage. In the study, we focused on teachers as socio-symbolic beings, and examined how their engagements with technology are framed, conditioned, and embedded in multi-levelled "technology encounters". These encounters represent teachers' daily engagements with digital media as everyday practices. Yet, such encounters also give rise to meaningful representations of technology that influence, in direct ways, further engagements with technology in the classroom and ultimately shape both the teaching and learning process. Our analysis indicates that these encounters are not only of practical value, but are also embedded in broader assemblages of history, symbolism, and culture.

In the next section, we contextualise the introduction and adoption of ICT for education in South African primary schools. Thereafter, we discuss some of the pertinent literature relating to social meaning(s) of technology. This presents a conceptual-theoretical lens through which we can interpret our participants' engagements

with technology for teaching and learning. Next, we present a background to the research project and outline its methodological approach. Finally, we explore the ways in which teachers meaningfully encounter technology in urban poor South African primary schools. From this analysis, we show how "meaning" is assembled and layered through (direct and indirect) encounters with technology at different levels. We argue for the importance of closely and critically scrutinising these encounters when seeking to understand the integration of technology for teaching and learning. Ultimately, we propose that these encounters are interpreted subjectively from the viewpoint of individual teachers, and culminate in the emergence of symbolic narratives: complex assemblages of symbolisms, meanings, understandings and interpretations that arise through and therefore come to influence further technology engagements. We argue that a closer examination of teachers' symbolic narratives can shed light on the reasons underpinning the processes of appropriation, integration -- or, alternatively, rejection -- of ICT in urban poor and under-resourced environments.

2. ICT for education in South African primary schools

Information and communication technology is a broad and sometimes fuzzy term. For the purposes of this study, we regard ICT generally as the electronic means of communicating information. This includes digital devices and services that facilitate the creation and rapid transfer of information. In the study, ICT was mainly encountered in the form of basic computer laboratories, consisting of desktop computers, a local area connection and digital projectors. We recognise that the analysis could therefore be confined to this narrow definition. However, as we will discuss in the following section, ICT is multidimensional and goes beyond mere physical or material means. It extends to matters of access, status, meaning, privilege, social movements, social relations and human development in the context of the global information society (Castells, 2015).

Since the introduction of computer facilities in South African schools, several complex factors seem to be influencing the capabilities of teachers and learners in adopting ICT. Studies of computer use in under-resourced schools have indicated that ICT adoption and skill levels can vary significantly (Gudmundsdottir, 2010). Teacher competence was identified as a highly impactful factor and was found to affect the abilities of learners to use technology effectively (Fanni, Tardini, Rega, Cantoni, & Van Zyl, 2010). Fieldwork research by Gudmundsdottir (2010) indicated that a great number of teachers struggled with the integration of ICT in the primary school classroom. This was especially true in schools where computer and Internet access were limited. Furthermore, many educators were not adequately prepared to deliver technology-supported lesson plans. They often had diminished interactions with their learners as a result.

In the case of the government-backed Khanya programme, teacher training was often felt to be inadequate or non-existent, thus limiting opportunities for competency

development (Bladergroen et al., 2012). Though Khanya's training programme included the use of educational software in the classroom, there was evidence of mismanagement and ineffective delivery. Globally, proponents of educational informatics strongly emphasise the importance of teacher training for the use of educational technology (Du Toit, 2015). In terms of the broader South African education sector, teacher development in ICT is recognised as an increasingly important skills requirement (DBE & DHET, 2011; Vandeyar, 2015). Several teacher-training campuses across the country have since incorporated ICT literacy components in pre- and in-service training curricula.

In the general pre-service training environment, there has been an over-emphasis on computer literacy and an under-emphasis on teaching with technology (Bladergroen et al., 2014). Past research (Chigona, Bladergroen, Cox, Dumas, & Van Zyl 2011) suggests that the skewed emphasis on technical skills development is only part of a broader problem. The adoption of ICT can be attributed to a combination of ICT skill levels, including content management proficiency and an understanding of pedagogy. Furthermore, the uptake of ICT in schools is also hampered by ineffective management policies. These often constrain the initial enthusiasm associated with computer use for pedagogical purposes. For example, teachers are not incentivised or encouraged to make frequent use of technological facilities (Bladergroen et al., 2012). Computer lab timetables are not properly administered, with computer rooms often being locked and inaccessible (Van Zyl, 2013). These factors are further inflated by the misappropriation of ICT infrastructure and the lack of general resources earmarked for ICT expansion.

Teacher and learner attitudes play an important role in the adoption and integration of digital technologies in primary schools (Cantrell & Visser, 2011). Attitude is a precursor to both behavioural intent and eventual behaviour (Van Zyl, 2013). Therefore, a positive disposition towards computer use is a prerequisite to acquiring higher levels of computer literacy and successful pedagogical adoption (Van Zyl, 2013). In addition to those already mentioned, several inhibiting attitudinal factors constrain positive ICT use. These include a lack of job satisfaction, lack of computer expertise and general computer anxiety. The anxiety relates to an innate suspicion of innovation and change, often hindering technological adoption (Cantrell & Visser, 2011).

Moreover, the learner is an important social component in the adoption of technology. The low skills levels of learners often challenge the introduction and integration of ICT in primary schools. This weakness is further undermined by poorly maintained facilities in resource-limited settings, hindering learner access to computer rooms. At the same time that lower skill levels are an expected part of the classroom environment, learners in resource-poor communities tend not to have computer access at home. They are thus deterred from practicing key concepts obtained in class (Bladergroen et al., 2012). Consequently, educators expend considerable time in

helping learners use the technology, instead of teaching the subject content. In these circumstances, teachers would rather avoid the technology entirely.

Overall, the literature describes a challenging and complex environment for the deployment of digital technologies in South African schools, where effective integration and adoption requires active participation at several levels, including government and policymakers, donors, civil society, school management, educators, and learners. Yet, within and across these levels, differing and even counterproductive attitudes toward technology emerge. These attitudes may instill or deter ICT acceptance and eventual adoption. It becomes important, then, to learn about the many perceptions of, and meaningful engagements with, technology in teaching and learning. Infrastructural and policy challenges aside, the many social meanings and representations that are attached to ICTs can significantly influence the adoption process. A study of social meanings attached to ICTs appears to be critical, therefore, in finding a more comprehensive means to solving the challenge of technological integration in schools (Chigona et al., 2011).

3. Social meaning of technology

This article adopts a social constructionist and sociocultural approach to the study of technology. Drawing jointly on social constructionism and sociocultural theory, this approach seeks to shed light on the importance of meaning attribution and symbolic interpretation in the analysis of technology adoption and appropriation in scholarly environments. Social constructionism highlights that technology, just like any human-made artefact, is a social construct (Pinch & Bijker, 2012). Technology is socially shaped during its development, driven by problem-posing, and reflects the needs and interests of creators and the meanings contained in their sociocultural contexts. Furthermore, the usage of technology is subject to interpretation and negotiation on the part of users and is adapted to a context of implementation (Weick, 1990). Proponents of actor-network theory (Callon, 2012; Latour, 1992) argue that the meanings, norms and values invested in technology design are reinforced by being embedded in compelling ways in technical design features.

Sociocultural theory adds further nuances to the perspective opened by social constructionism, through its close attention to the nexus of technology, human action and the cultural and historical context that embeds the action (Wertsch, 1998, p. 24). Its core principle is that human action is mediated using tools that have been created in a sociocultural system and transmitted to future generations that modify and pass them on (Rogoff, 2003, p. 51). The study of technology is therefore focused on its instrumentality, or its capacity to mediate action. Sociocultural instrumentality is distinguished by two important attributes. Firstly, the instrumental quality dwells on sociocultural and historical factors. The capacity of a tool to mediate certain kinds of activities reflects axiological systems and complex codes of meaning attribution prevalent in a sociocultural system and evolving in time. Secondly,

the study of instrumentality sees the agent, the tool and the action as composing a whole. Mediated action, the core unit of analysis in sociocultural theory, refers to the "agent-acting-with-mediational-means", an expression that suggests there is an almost inseparability between the agent and the tools that mediate action (Wertsch, 1998, pp. 26-27).

Drawing jointly from social constructionism and sociocultural theory, a few aspects pertaining to the social embeddedness of technology can be highlighted. With respect to their definition, ICTs are not only technical tools; they include artefacts, but also the associated practices that they enable and the social arrangements that facilitate their production, distribution and usage (Lievrouw & Livingstone, 2006, pp. 2-3). Technologies are concretisations of social relations instantiated in specific cultural contexts, so that their impacts cannot be anticipated when the same tools are used in different settings (Suchman, 2007). However, the social dimension in both technology design and usage is often invisible. Social practices and social norms become established and unquestioned, so that their social shaping is obscured (Latour, 1992; Lievrouw & Livingstone, 2006).

It is by adopting a social embeddedness perspective that some of the tensions associated with the introduction of educational technology in the Global South can be examined. Technology designed and developed in a specific sociocultural system enters contexts of use that are new and different, where its appropriation is socially shaped on different grounds. When technology is integrated in a new scholarly environment, both teachers and learners re-imagine technology and its uses from a standpoint firmly rooted in their own sociocultural contexts. The functional and the socio-symbolic attributes of technology can clash and spur tensions in this process. Moreover, meanings of technology are intricately connected with teaching and learning attitudes and are important in determining technology use and integration by both teachers and learners. As Van Zyl (2013) and Sabiescu et al. (2013) show, the meanings attributed to technology by pre-service teachers in South Africa are context-bound and display attributes generated by the experience of living in a resource-limited context. In this article, we go one step further and discuss how meanings attributed to technology are formed and how they are articulated in close relation with technology encounters.

4. Background to the project: Participants and methodology

The multilateral study, reported in this article, officially commenced in late 2008 and involved two Western Cape universities, the Western Cape Education Department and a university in Switzerland. The research was originally designed as a quasi-experimental (mixed method) study to determine the impact of digital technology on teaching and learning in resource-restricted (urban poor) primary schools. As a mixed methods study, the research made use of controlled experiments, questionnaires, as well as in-depth qualitative approaches, namely ethnographic fieldwork.

For reference, we give some background to the context and participants in the overall study. However, we primarily discuss the ethnographic component and some of the primary insights generated by it.

Between the years 2010 and 2013, 120 participants from six primary schools in the Metro Central Education District of Cape Town were engaged as part of the study. Participants were comprised mainly of teachers, principals and managerial staff of the schools' computer laboratories. Schools were originally grouped in two categories, to allow for a quasi-experiment (Fanni et al., 2010). However, concerning the ethnographic component, all six schools were involved at the same time.

The six participating schools were generally under-resourced and under-equipped. At the time of the fieldwork, all schools were understaffed, with little access to technology resources. Learner: PC ratios were relatively high (between 16:1 and 20:1), a criterion for participation in the Khanya programme. On the surface, then, the six schools were comparable. However, this veils the true heterogeneity across the schools. The population of Cape Town is deeply polarised along race, class, and language divisions. Communities present diverse histories, experiences and sociocultural norms and values. In this way, schools are at once heterogeneous and embedded in larger political and educational structures.

In this article, we report on those ethnographic activities that manifested as in-depth discussions, participant observations, and critical reflections with participants at the six schools. These have long been the principal methods in anthropological research (Bernard, 1998). In addition, participants were regularly engaged through weekly computer literacy workshops, in which the ethnographers acted as facilitators and mentors. In this way, the research became action-oriented, wherein the researchers had some influence on participants' daily environments and work life.

The ethnographic inquiry was generally informal in nature, and was responsive to the time constraints and agendas of the participants. In this sense, the research approach was dictated by the empirical field. Semi-formal interviewing (110 interviews, following a general interview protocol) was complemented by informal discussions that were open, flexible and iterative. The researchers also focused on the contexts of discussion, that is those cultural, interpersonal and political dynamics that appeared to govern the social interaction. In this sense, the ethnographic process was strongly informed through the practice of self-reflection (Scholte, 1972).

5. Towards an understanding of meaningful representations of digital technology

In what follows, we document some of the leading insights gathered during our ethnographic journey. Specifically, we unpack the "realm" of the primary school teacher in a critical and contextual manner. This will be done in respect of the various social interactions and technology encounters that take place in teachers' daily lives. This

discussion forms the starting point of a broader symbolic narrative. In describing this narrative, we intend to depict teachers as socio-symbolic beings who encounter digital technology in diverse, meaningful and contrasting ways. Such encounters are complex and multifaceted, and form part of deep symbolic assemblages of meaning, culture, history and technology.

The social function of the teacher

Teachers are not reducible to instructors, proverbially bound to classrooms and chalkboards. Rather, their duties range from being facilitators of knowledge, to being social workers and counsellors. This multifaceted role is particularly important in volatile contexts where students have experienced poverty, abuse and trauma. When queried on his daily activities, one senior teacher listed his primary functions:

> Educate; Inform students about the technicalities of growing up; Upskilling the students to help them to be productive; Social work counselling [for] both parents and students; Moulding the students and help them see opportunities; Help them deal with the results of the social circumstances and [the] political climate, and [help them] rise above all that.

The complexity of the teacher's role quickly becomes apparent. The same respondent spoke of his responsibility to learners:

> At Grade R, they come in as "clean slates" that have different languages, cultures, beliefs and have only been exposed to their families. So we then help them not [to] operate from ignorance and fear about each other, and help them transition to accommodating each other.

Such responses convey the miscellany of social actions in the primary school environment. Teachers fulfil the role of secondary parents and guide students in dealing with their surroundings. They harness and mould those crucial skills learners will require in becoming productive members of society. In environments marred by poverty, marginalisation and inequality, educators also act as counsellors, helping students transition from positions of "ignorance and fear" to positions of accommodating diversity. Such roles seem to represent some of the main educational functions of teachers, as voiced by the respondents:

> I try by all means to give whatever I've got to put it through to the learners as much as I can. Most of the students have been traumatised. I majored in Psychology and Linguistics, so I am comfortable counselling students. I also talk to them because I want to see them achieve their goals.

Teachers regard their roles as being holistic. They are not only central to the pedagogical process, but also to the socialisation of young persons. They are required, in this way, to possess skills and capabilities that far exceed conventional teacher train-

ing. Such types of social relations seem to dominate much of teacher group life. It is then important to acknowledge that the introduction and use of technology would always be contained within the idiosyncrasies of everyday teacher relations. Considering this, the research opened up to a new analytical perspective with respect to ICT integration in schools, asking the following: How can ICTs, as artefacts initially alien to teachers, be integrated so that they are not merely instructional devices in a simplistic teaching-as-information-delivery paradigm, but that they enable teachers to both express their multifaceted roles and enact meaningful teaching-learning interactions?

Encountering digital technology in meaningful ways

During the ethnographic study, we observed how teachers approached, appropriated and negotiated their understandings of ICT. In concrete terms, we refer to this as "technology encounters". Importantly, the encounter cannot be defined in its lay sense alone, which refers to a casual interaction or meeting. Rather, we argue that the encounter is an interpretive and symbolic act. The encounter is not independent or isolated, but entwined in a complex web of interactions. The encounter generally takes place spontaneously and intuitively, and includes interactions with both material and intangible objects (Michalski, 2013). We do not separate ourselves as ethnographers from those encounters exhibited by teachers. Rather, we recognise our own role in shaping some of the technology encounters in the primary schools partaking in our study.

In the following passages, we present technology encounters in terms of how they take place across three intersecting levels. First, we describe macro- and meso-level encounters. These are perhaps intangible at a personal level, but represent the higher order understandings of, and experiences with, technology. These aspects shape the micro-level encounter and inform the local technology experience. After describing some micro encounters, we contextualise the spectrum of encounters within a holistic symbolic narrative.

Macro- and meso-level encounters

Encounters at macro and meso levels are mostly discernible as formal, high-level movements, discussions and policies. At a macro level, referring to worldwide movements and discourses, we identify three critical components: (1) an emerging global state of hyper-connectivity, which propels the development of infrastructure and new techno-capabilities; (2) the purported transformative capacities of digital technology, offering improved functionality and efficiency, among many others; and (3) the many perils of hyper-connectivity that instil the "expectation to change" and can breed anxiety, fear and resistance (Thierer, 2013). Jointly, these aspects are visible at a macro level, but have real implications for meso- (national, regional) and micro- (local, personal) levels.

Following the ending of apartheid in 1994, the South African government gradually pursued the adoption of technology in its policies of regional and local development. Below, we list some of the influential factors at this meso-level:

- The ongoing challenge of addressing systemic poverty, ill health, violent crime, and unemployment.
- The roots of an oppressive past, which contributed to the unequal distribution of resources in the country (Oyedemi, 2009).
- The strong belief that technology can address many of the region's development challenges, notably poverty (May, Waema, & Bjåstad, 2014).
- The local materialisation of the "digital divide" as a state of technological inequality between the many South African groups and communities. Individual and regional differences are polarised along the lines of social class, geography (urban and rural) and access to opportunity (information "haves" and "have-nots") (Pick & Sarkar, 2015).
- Policies to address the digital and development imbalance nationwide: Strategic imperatives include the Ten-Year Innovation Plan (2008-2018), the White Paper on e-Education (2004), and the mandate of the Presidential National Commission on Information Society and Development (PNC on ISAD) (Averweg & Erwin, 2010).
- The implementation of technology-for-development initiatives country- and region-wide (James, 2004). In the domain of education, these have included technology access programmes, digital content development initiatives and user-driven projects. In the Western Cape, the Khanya Project is one such example.
- At both macro- and meso-levels, there is a clear sense of techno-optimism: Local institutions purposefully leverage digital technology in the belief that it can support development, not least in the educational sphere. At a micro level, however, this plays out in diverse ways.

Micro-level encounters

> For me, ICT is how you link with the global world in terms of sharing knowledge, information, and resources with people that are not here with you. For me, it also ties up with skills, sharing skills. It has to do with skills development. It also makes you aware of the changes that are out there by using ICT. And it opens up your eyes and it gives news. It brings the other world here. It makes things easier for me.

The passage above, expressed by a female teacher at a participating school, represents one of the many local understandings of ICT. When asked to reflect on what she meant by technology and the kinds of functions it could offer society and her as an educator, this teacher alluded to the connectedness of ICT, of the possibility it provides to share information, knowledge and resources. Interestingly, the respon-

dent referenced skills sharing and development as advantages of ICT. Perhaps most significantly, she described the ability of ICT to "bring the other world here". This echoes the opinions of other teachers interviewed:

> Especially our learners, who don't really experience outdoor life, outdoor activities, they don't venture out there, they don't see things. Some of them have never been close to Table Mountain, although they see it from our school. They need to be shown these things. You don't want to accuse them of ignorance, but their lack of experience, it's alarming. They don't experience your lifestyle. Showing them opens their eyes up to what is around them.

> Their experiences revolve around what happens in the townships, because that is where they live. You try to broaden their horizons, to show them. For them, this is the best thing and that is why they enjoy these computers. They don't usually have access to it. And showing them clips about what Cape Town looks like. You think, wow, here you are driving around Cape Town every day, and they've got to see it. So that's part of the value, the exposure.

Such expressions are only specific examples of some of the social representations of ICT in under-resourced school settings. These teachers assume a characteristic "universal" view, suggestive of what Brown and Hart (2012) term a globalisation discourse. Teachers also say that ICT makes their lives easier, what Brown and Hart term a productivity discourse:

> It helps us a lot, the ICT. Before I didn't know about email and now I know a lot. And as a result, now I am going to Langa. So now I'm using the computer. It is very, very useful.

> It makes our life easy. It is easy to get. We don't struggle like before. Like setting papers, using that old typewriter. Now it is just "click, click" and everything we got. It is very, very easy.

> It is easy now to get a lot of information, especially when there is the Internet here. So, most of the time we just go there and we will get the information. At least everything is easier to find. If it is easier to get, of course we have access to it.

These are some of many instances of globalisation and productivity themes to have emerged from our discussions with teachers. The general sentiment is that technology makes life easier, makes information accessible, and increases productivity at work. The functional value of technology is also closely linked to its educational benefits:

> To me computers are like a supporting material. I like to use computers,

> because the learners find it much more interesting to learn with computers.

Teachers are aware of the educational benefits of ICTs. For some, ICTs offer interactive engagement with the unknown or external world. Learners can be exposed to previously unfamiliar lifestyles, activities, and events. Their horizons are broadened as the access to information is increased. For teachers, ICTs are particularly useful as "supporting material" in the classroom. Learners are engaged, excitedly, in the educational process. These types of responses indicate the sense of optimism found among most teachers interviewed.

> Because we've got learners who, when they come to the computer room, they are so excited they can't wait. I think this has a lot of impact, because when I take my kids they are so excited... because there's a lot of information that they are getting from the computers.

Yet the implications of digital technology in these schools extend beyond its clear functional and educational value. Some teachers alluded to the "transformative capacities" of technology:

> It sharpens their minds and [they] become critical thinkers, because they are viewing the information. ICT enlightens.

> So the teacher feels that they [are] imparting far more than just the basic lessons. So the technology opens up so many more avenues, so many more horizons for them. They can see so many more things, do so many more things. So it is a very empowering tool.

The transformative benefits of technology are evident in its ability to "expose", to "enlighten" and to "empower". Beyond its immediate functional and educational properties, then, ICTs reveal other affordances. Despite this, several conflicting opinions surfaced as well, somewhat negating the techno-enthusiasm of the majority. Not all teachers were confident in using digital technology for educational (or other) purposes:

> I do not know how to use the Internet, which tends to limit me.

> Well from my experience of using the computers, sometimes you get stuck and you don't know what to do and this is really frustrating.

> But they've got a negative attitude. They said, "you want to take part of our time now for this training, but we don't want that nonsense. We can teach without computers. We can manage."

These excerpts reveal many challenges and frustrations related to ICT use. Because

of the nature of the participating schools, the teachers have limited access to digital technology. This is worsened by technical illiteracy, time constraints and negative attitudes. In this regard, participants alluded to a divide between "natives and immigrants" within the primary school. This refers to the commonly accepted trope within ICT-for-education: Young people (natives) have grown up with computers and the Internet, and are naturally proficient with new digital technologies and spaces (Rapetti & Cantoni, 2012). Conversely, older people (immigrants) will always be a step behind in their dealings with the digital (Bayne & Ross, 2007). This belief affects teachers' professional experience with technology:

> We got [have] the problem because us as teachers, we are not coming from this generation, so we are not equipped enough for this. Because we only started to be computer literate only now while we [are] already teachers.
>
> Yes because, like I said, I had never had any experience with computers, I could only switch it on and off. But we are old with [for] this!

These experiences indicate a sense of computer anxiety. Some teachers are not proficient in using digital technology and do not have confidence in their own abilities. Generally, these teachers have had minimal exposure to digital technologies. Some refer to a generational gap: teachers versus students, natives versus immigrants, digital versus analogue. This belief may itself reinforce any perceived disconnect between groups, because teachers may fear the changes that are expected of them (Bayne & Ross, 2007).

Encountering technology symbolically

In a seminal work, Prasad (1993) discusses the symbolic processes involved in the computerisation of work in an organisation. Citing Turkle (1984), she examines the "computer" as an extraordinarily meaningful technology, holding different meanings for different people. Prasad (1993) describes the "magical symbolism" of the computer in the workplace, and identifies those "ritualistic assurances" inherent in an automated organisation. Again, citing Turkle (1984), she lambasts studies that exclusively focus on the "instrumental computer", while ignoring what she calls the "subjective computer". While the former holds only practical significance, the latter is a symbolic object, conveying multiple personal meanings.

More than two decades on, the notion of the subjective computer is very much relevant in the study of ICT in educational settings. As we gathered from the field study, the subjective computer can take the form of "multiple symbolisms", encounters, or experiences, and is located within the realm of human meaning and related meaningful action (Prasad, 1993). In this regard, every organisational situation is likely to be filled with multiple and contested interpretations and meanings. Therefore, in the primary school environment, one should expect a diversity of perspectives and

meanings that do not necessarily accord with any universal imperative.

Our emphasis remains on micro meanings, those held in multiple everyday contexts, such as particular areas, functions and enclaves within an organisation (Prasad, 1993). Within these domains, individuals symbolically interact with material and intangible objects. The outcome of this interaction is a series of multiple symbolisms, or representations. Such symbolisms vary within and between different organisational levels, individuals, and communities. They should not be reduced to stand-alone or isolated encounters; rather, they are embedded in a complex assemblage of symbolisms, an ecology of meaning.

Our observations at the various primary schools revealed contradictory technology encounters at the micro level. Teachers were generally positive as to the functional role that technology can play in teaching and learning. In general, we observed an overwhelming sense of technology enthusiasm at all the participating schools. In some cases, this enthusiasm took the form of "gizmo idolatry" (Leff & Finucane, 2008), the conviction that a technological approach is intrinsically better than one that is less technological. In contrast, the teachers had also had many frustrating and negative experiences with technology. They were fearful of the expectation to change their behaviour, to learn new approaches, or to embrace technology. In many cases, this was due to self-induced fear and not actual negative encounters. Teachers could perceive technology to be monstrous, generationally confined, or challenging to understand. For instance:

> I can be very honest with you, when I started, came back into teaching, I was very afraid of the computer. It was like a monster to me, you know. I was afraid even to touch my children's computer, because I didn't know the computer.

6. Analytical discussion: A complex assemblage of meaning

The analysis of these contradictions reveals an inherent tension between the functional and socio-symbolic roles of technology, fuelled by direct and indirect technology encounters. While they are expressed at the micro-level, influences from the macro- and meso- levels have an important bearing. A powerful stimulus towards technology adoption appears to have been provided by South African national discourses emphasising the importance of adopting ICT. These discourses give prominence to the functional attributes of ICTs. At the same time, through the depictions of the many advantages associated with their educational integration, ICTs quickly acquire a dimension associated with progress, change and modernity. This dimension informs the socio-symbolic role of ICT in teachers' realms.

At the outset of the study, several utilitarian themes, including *pragmatism* and *necessity*, were observed as the foremost technology experiences:

Pragmatism emerged as a dominant encounter in our exploration. ICT is symbolised as being practical and functional. It is generally useful and necessary for administrative purposes and classroom management. In some cases, this extends to teaching and learning; it becomes valuable as an educational technology.

Necessity emerged as another dominant symbolic encounter in our study. Digital technologies are critical to the progress of the school and to the advancement of the teaching profession. This is promulgated at a national level, in which the need for ICT gains momentum in policy, regional programmes and public discourse. In this vein, the embrace of digital technologies is embedded within an educational directive; it is pertinent in developing the capacities of the teacher. This symbol is also tied to the "expectation to change". As with other symbols, organisational necessity is often implicit or inherent, that is, technology becomes unquestionably necessary.

In additionl to these pragmatic approaches, two additonal, contradictory themes emerged, broadly characterised by elements of either *pessimism* or *optimism*:

Pessimist narratives convey mistrust and cynicism towards technology integration. Many educators doubt the transformative benefits of ICT, or are sceptical of its purported value to the classroom environment. Although this a common perception, it is often overshadowed by enthusiasm or pragmatism. One reason for this is the fear of being ostracised, of being labelled as backward or incompetent (Sabiescu et al., 2013; Van Zyl, 2013). Negative or sceptical attitudes are associated with other strong themes, namely *frustration* and *fear*.

- *Frustration* represents actual negative encounters with technology. Frustrations are tied to a series of negatives, including lack of bandwidth or electricity, mismanaged timetables, lack of know-how, overpopulated classrooms, time pressures, and the like. Such encounters are frequent, but are often suppressed by dominant positive interactions.
- *Fear* can result from frustrating or negative encounters, but can also precede an actual encounter, manifested as a sense of distance and associated with a lack of capacity to handle what are perceived as complex technical systems. Fear also manifests through strong beliefs of generational differences. Older respondents tended to resort to such perceptions and were seemingly afraid of technological interaction. This affected their confidence and overall willingness to engage with ICT, to the point of complete avoidance.

Optimism, conversely, relates to the potential transformative capacities of ICT and to its "promises" of change. Optimism is associated with some nuanced symbolic narratives, ranging from a view of technology as entertaining and engaging, to a pronounced *romantic vision* of technology, to a belief in its *capacity to enlighten* and transform. At an initial level, the engagement with digital technology is recurrently associated with expression of enjoyment, fun, excitement and interest. We found this

related especially to the learner community, who tended to be uncontrollably eager to visit computer laboratories each week. Many teachers were equally enthusiastic, particularly in terms of the interactive features offered by technology in the classroom.

- *Enlightenment narratives* allude to a state of technology utopia, in which ICTs instil a sense of transformation and uplifted human capacities. Here, teachers perceive ICTs as inherently good or desired and stress their transformative capacities in education and professional practice.
- With a more pronounced imaginative dimension, the theme of *romanticism* represents instances where respondents romanticise the use of technologies. It also pertains to cases in which teachers idolise technology, for example, as seen in the overt security measures for computer labs. This symbol also alludes to instances in which digital technologies are attributed with human and animal characteristics (anthropomorphism). In such cases, digital objects are thought of as lifelike, with attributes that remind of humans or creatures, for example the "monster" earlier described.

The idea of anthropomorphism underpinning some of these symbolic narratives is of particular interest, given its allusion to human qualities. This links closely to the socialisation and cerebrality of technology, in which computers are associated with the human presence, modelled on the principles of behaviour and intelligence (Case, 2007; Haraway, 1991; Prasad, 1993). This notion of "human-like" technology was not fully explored during the fieldwork. Rather, we observed it as a casual occurrence in the context of everyday use, especially during formal training sessions at each of the schools. We generally perceived anthropomorphist symbols, such as loyalty, unreliability, interactivity or sociability, temperamentality and indifference (unresponsiveness, "death"). In these instances, the computer system and associated technologies seemed to acquire human characteristics (Prasad, 1993). In some cases, teachers appeared to be demonstrative toward computer machines and laboratories. This resulted in the exaggerated safekeeping of labs, rendering them inaccessible for long periods. Such sentiments are broadly associated with technology idolatry, as earlier discussed (Nickel, 2010).

These symbolisms, among many others, converge within an assemblage of meaning. Specifically, we term this as a "symbolic narrative", one that contains the multiple, interpreted realities that arise in the engagement with technology. This narrative offers a broadened and complex view of those micro-encounters presented earlier. Ultimately, we found that the symbolic narrative that characterises the technology-in-education experience is, paradoxically, both perceptible and elusive. Many of the foremost symbols we identified emerged ambiguously or obscurely. Teachers, for instance, desired to use technology, but also insulated themselves against it. In public (e.g., interviews), they were passionate and optimistic about educational technologies. In practice, they were often passive and indifferent to acquiring digital literacy skills (Bladergroen et al., 2012; Chigona et al., 2011). Many of the teachers, more-

over, had not encountered ICTs as a real educational tool; hence there existed no benchmark by which to gauge successful adoption.

The diversity of themes described above could be interpreted in different ways at various interactional levels. Considering this case, ICTs may simultaneously represent elements of chaos or turmoil and, at the same time, elements of professionalism and educational enlightenment. The images and meanings of these objects are not homogeneous and need to be understood in terms of their contextual manifestations (Prasad, 1993). It would not be accurate to claim that, for all respondents, digital technology symbolises pragmatism or organisational efficiency. Consideration also needs to be given to personal or individual meaning. A complex assemblage of meaning transpires through a collective or individual sense-making.

7. Concluding thoughts

In this article, we have discussed how teachers in South African primary schools encounter digital technology in a meaningful and symbolic manner. The encounter is an interpretive social capacity that forms the basis of interaction. It is impractical to seek to canvass all of the many differing encounters that take place in such a complex environment. Rather, it is the systematic recognition of individual and collective sense-making that remains of concern. The very nature of meaning creation, then, should form the basis of future investigations regarding the use of technology in education.

Furthermore, we discussed how encounters are located and enacted across macro-, meso- and micro-levels. At the macro-level, the globalisation of digital technology has strongly affected the teaching profession. This resonates both nationally and regionally in South Africa. Leading actors in government, industry and civil society have pursued technological progress by means of ICT access and integration programmes in teaching and learning. This has permeated the micro-level, at which primary schools are introduced to local ICT-for-education initiatives such as the Khanya project.

At this more nuanced micro-level, we observe the institutionalisation of the "technology imperative": the use of technology out of the (deterministic) belief that it is good or beneficial. Examined more closely, we notice this imperative to be enacted as a symbolic reality. This represents an alluring state of new technology, in which it is viewed as an instrumental symbol of modernity. Our exploration deepens to discover related symbolisms: meaningful encounters espoused by teachers, to which they ascribe value. Some of the multiple symbolisms of ICTs include pragmatism, organisational necessity, cynicism, digital immigration, fear, romanticism, utopianism and enlightenment. These are just some of the descriptors that we can assign to technology encounters.

Notably, macro-meso contextual issues, and specifically organisational and work-related dynamics, may affect teachers' attitudes towards technology. It is therefore likely that encounters and meanings that arise in environments where the use of technology is voluntary may be different. The symbolisms thus far described may therefore not be typical of disadvantaged primary schools or of teachers in general. In this vein, symbolic encounters are highly situational and may vary across institutional, personal and cultural modalities.

Overall, the multiple experiences of individual teachers converge within a fluid symbolic narrative. This narrative is a collection (assemblage) of meaning, history, culture, and technology. This aspect should be recognised and deepened in future studies of technology in education. Specifically, researchers should ask how encounters come to be, how meaning is assembled, and how the notion of a symbolic narrative can help us understand the integration of technology in teaching and learning.

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Reproductive Health Information Needs and Access among Rural Women in Nigeria: A Study of Nsukka Zone in Enugu State

Ifeanyi J. Ezema
Librarian, Nnamdi Azikiwe Library, University of Nigeria, Nsukka; and Post-Doctoral Fellow, Department of Information Science, University of South Africa (UNISA), Pretoria

Abstract
This article presents a study of the reproductive health information needs and access practices of rural women in Nsukka Cultural Zone, Enugu State, South East Nigeria. Three hundred and fifty women from 14 rural Nsukka communities were surveyed and 335 responses analysed. It was found that the main reproductive health information needs of the women were related to infertility; use of contraception; abortion; prevention of sexually transmitted diseases; antenatal care; and postnatal care. The main existing sources of reproductive health information were found to be: friends and relations; hospitals and health centres; churches; women's organisations; and radio and television. Fewer than half (46%) of the women participants were found to be accessing reproductive health information using their mobile phones. The author recommends enhanced rural development approaches that include: information provision through mobile communications; opening of rural libraries and information centres with Internet hubs; and sustainable adult literacy campaigns focused on reproductive health information.

Keywords
reproductive health information, information access, rural communities, mobile information access, Nigeria

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1. Introduction: The problem of reproductive health information access

Women in rural Nigeria require information to advance their reproductive health. The study outlined in this article examined the reproductive health information needs of rural women in the Nsukka Cultural Zone of Enugu State in South East Nigeria. Specifically, the study sought to: identify the major reproductive health information needs of women; find out what were the existing governmental and/or non-governmental information access structures in the women's localities that could meet these information needs; determine the women's existing sources of reproductive health information; determine the challenges faced by women in accessing reproductive health information; and recommend strategies for improved access to reproductive health information.

Since the middle of the 20th century, there has been a gradual increase in awareness of the important role of women in households and in socio-economic development. The United Nations (UN) signed a charter for equal rights for women in 1945. A call on the global community for the increased involvement of women in national and international affairs accelerated gender studies. This call was given international support when the UN declared 1975 International Women's Year. The same year saw convocation of the first International Women's Conference in Mexico, followed by conferences in Copenhagen (1980), Nairobi (1985) and Beijing (1995) (UN, 1995). In these conferences, women's reproductive health and welfare in rural areas topped the agenda (Mongella, 1995). The concern about women in rural areas, particularly in developing countries, relates to their literacy rates, poverty, and vulnerability to diseases and social inequalities, despite their critical role in development (Kongolo & Bamgose, 2002). It is for these reasons that the UN (1995) called for abolition of all forms of discrimination against women and You, Hug and Anthony (2015) called for the empowerment of women so as to promote their access to reproductive health. Provision of adequate and timely health information is critical to empowering women in developing countries. Women seek health information for themselves and their families (Wathen & Harris, 2007). Health information is critical in health care delivery and health promotion, as it provides the direction and rationale for positive health behaviours, facilitates efficient treatments, and enhances proper decisions on health matters (Kreps, 2005). According to Saleh and Lasisi (2010), health information constitutes 20% of the information needs of rural women in Northern Nigeria. Usually, reproductive health information constitutes a large proportion of these health information needs.

Women's socio-economic conditions affect their reproductive health. Women suffer discrimination in many aspects of life, including health care discrimination (Okojie, 1997; WHO, 2014a), economic discrimination (Goutier 1995; Fatusi & Hindin, 2010; Daley & Pallas, 2014), nutritional discrimination (Shiva, 1993; Tinker et al.,

1994; Ngwena, Brookman-Amissah, & Skuster, 2015), educational discrimination (Martin, 1996) and political discrimination (Mongella, 1995; Nnadi, 2012). In many developing countries, this discrimination starts early in life. Developing-world women are often economically dependent on men (Piot, Greener & Russell, 2007) and, accordingly, tend to resort to means of survival that lead to high-risk behaviours, such as prostitution, early marriage, teenage pregnancy and abortion. These problems are exacerbated in rural areas, where access to health care facilities and up-to-date health information is often lacking.

South East Nigeria, one of six geographical zones in the country, is made up of five states, namely Abia, Anambra, Ebonyi, Enugu and Imo. With respect to demographics, the 2006 census estimated the population of the South East zone at 16.4 million, comprised of 8,246,604 females and 8,184,951 males (National Population Commission, 2006). The population of the South East zone is mainly agrarian, with a sizeable proportion of traders and civil servants. Enugu, one of the states in the zone, has predominantly a rural population, mostly focused on subsistence farming, with only a few of these rural people engaged in trading and provision of public services. In the urban areas of Enugu State, trading is the dominant occupation, followed by services, with a small proportion of the population engaged in manufacturing activities. Nsukka Zone is one of the three Cultural Zones in Enugu State.

2. Rural women's reproductive health challenges and information needs

Studies have identified teenage pregnancy and abortion as major challenges (National Population Commission, 2009; Okereke, 2010). Evidence from developing countries shows that teenage mothers are likely to face severe complications during delivery, leading to high mortality rates (Fatusi & Hindin, 2010; Rasheed, Abdelmonem & Amin, 2011; UNICEF, 2005). A report by the World Health Organisation (WHO, 2016) indicates that there are 520 deaths per 100,000 unsafe abortions in sub-Saharan Africa. According to Leke (2014), the African continent has the highest abortion-related maternal mortality ratio, with 100 abortion-related deaths against 100,000 live births in 1990 and 80 deaths against 100,000 live births in 2008, four times higher than Asia and eight times higher than Latin America. Cohen (2012) and Geleto and Markos (2015) have found that abortion is becoming increasingly concentrated in developing countries with high rates of poverty and illiteracy, where these abortions are typically conducted in a clandestine and unsafe manner.

Apart from this, some traditional practices such as female genital mutilation, virginity tests, and violence related to dowry and widowhood, compound the reproductive health challenges of women in developing countries. Among these, female genital mutilation poses the most reproductive health challenges and seems to have a wider

geographical spread globally. Victims of female genital mutilation can be infected with illnesses such as HIV/AIDS, tetanus or gangrene, and suffer from urine retention, injury and long-term reproductive problems. According to the 1995 UN figures (UN, 1995), about 2 million girls living in 26 African countries and in a few Asian countries were estimated to be at risk from this practice every year. More recently, Yoder, Wang and Johansen (2013) estimated the total number of women aged 15 years and above who had undergone genital mutilation in 27 African countries and Yemen at 87 million. UNICEF (2013) and WHO (2014b) have reported that more than 125 million girls and women in 29 countries in Africa and the Middle East are victims of genital mutilation. The practice continues despite its abolition by the UN General Assembly in 1954 (UN, 1995).

Another reproductive health challenge is increasing violence against women. WHO (2013) found that 35% of women globally had experienced physical and/or sexual intimate-partner violence, or non-partner sexual violence, while 38% of all murders of women were committed by intimate partners. Rape has been identified as one of the greatest global health challenges for women.

India and Nigeria account for one third of all global maternal deaths (WHO, 2014). Doctor et al. (2012) observed that maternal mortality in Northern Nigeria appeared to be the worst in the world, with 1,000 maternal deaths per 100,000 live births in 2008. Reproductive health challenges and high mortality rates have been attributed partly to lack of reproductive health information (UN, 1996; Doctor et al., 2012, Rai et al., 2012).

The HIV/AIDS scourge in sub-Saharan Africa is another serious reproductive health challenge for women. Early exposure to sexual experience and lack of sex education expose females to unwanted pregnancy and sexually transmitted diseases including HIV/AIDS. A recent study by Lince-Deroche, Hargey, Holt and Shocket (2015) found that young women in South Africa are at high risk of unintended pregnancy and HIV-AIDS infection. A much earlier study by UNDP (1993) found that woman between 15 and 25 years accounted for 70% of HIV infection among females globally. The HIV/AIDS prevalence rate in South East Nigeria has been estimated at 3.1% (UNAIDS, 2015).

3. Reproductive health information access and dissemination

Nigeria's rural areas suffer from inadequate information access, with major contributors to this deficit being high levels of poverty, irregular power supply, and, in turn, inadequate electronic communications access (mobile, Internet). Access to electronic information is a major challenge in the rural areas due to irregular power supply and low Internet bandwidth, compounded by high levels of poverty among the rural dwellers, making it difficult for them to purchase mobile phones. This challenge has been underscored in the studies of Akinfaderin-Agarau, Chirtau,

Ekponimo and Power (2012) and Okuboyejo and Eyesan (2014). Information has been identified as a vital tool in combatting health challenges facing women in the developing-world (Nwagwu & Ajama, 2011; Ezema & Ugwuanyi, 2014; Murakami et al., 2015) and in improving women's reproductive health (Martin, 1996; Thapa, 1996). Martin (1996, p. 181) found that "most of the unnecessary deaths and disease burden could be prevented through application of low-cost effective technologies in medical care and provision of health information to parents and child care-takers". Lince-Deroche et al. (2015) found that one of the most successful methods of reducing health challenges, such as unintended pregnancy and HIV/AIDS infection, is women's access to reproductive health information. Dipeolu (1992) and Ravallion, Van de Walle, Dutta and Murgai (2015) document the neglect of the supportive roles of library and information centres in promoting health information provision in Nigeria. Literature demonstrates the paucity of reproductive health information available to rural women in Nigeria, while what is available is often oral (Nwagwu & Ajama, 2011), or not packaged in languages and format familiar to them.

Advances in information and communication technology (ICT) provide a new platform for health information dissemination in the form of mobile health (m-health) information. Mitchell, Bull, Kiwanuka and Ybarra (2011), in a study of secondary students in Uganda, found that 61% of students agreed that they can access text messages from their phones for the prevention of HIV/AIDS, an indication of the increasing use of m-health in Uganda. Lester et al. (2010) found that patients using text messaging, through their mobile phones, linked to their antiretroviral therapy (ART) adherence, had significantly greater ART adherence rates and rates of viral suppression compared to patients not usign the text-messagingt service**.** In Kenya, Zurovac et al. (2011) found the use of text messages to be efficient in the prevention and treatment of malaria. The use of social media platforms such as Twitter has also been found to be effective in health information dissemination (Scanfeld, Scanfeld & Larson, 2010). This demonstrates the potential for effectiveness of m-health in health information dissemination.

In Nigeria, the use of the mobile phone in addressing reproductive health challenges has been investigated by Akinfaderin-Agarau et al. (2012), who found that, while there is high access to mobile phones among adolescent girls and young women, their access to mobile sexual reproductive information and services is low. It was found that the major barriers to the utilisation of the mobile phone for reproductive health information are the cost of the services and lack of awareness. Similarly, Olatokun and Adeboyejo (2009), investigating the use of ICT by reproductive health workers (RHWs) in University College Hospital Ibadan, Nigeria, found extensive use of ICT among them. However, a major challenge to utilisation was erratic public power supply. Egbule, Agwu and Uzokwe (2013) found the use of mobile phones to be efficient in addressing the information needs of rural dwellers in Delta State, Nigeria. The study revealed that about 97% of the respondents (extension workers)

had mobile phones and interactions with the rural dwellers were through phone calls (84.4%) and text messages (71.9%). Okuboyejo and Eyesan (2014) developed a mobile technology-based alert system using text messages and voice features of mobile phones to remind patients of dosing schedules and adherence to medical appointments for outpatients.

4. Methodological discussion: Survey of women respondents in rural Nsukka Zone, Enugu State

My study was conducted in 2015. Enugu State was chosen for this study because of the large population of rural dwellers and the observed prevalence of reproductive health challenges. Nsukka is one of three Cultural Zones in Enugu State. Nsukka is made up of seven local government areas and hosts the country's first indigenous (established post-independence) university, the University of Nigeria, Nsukka. The majority of the communities in Nsukka Zone, being rural-agrarian, lack basic facilities, such as good road networks, good health facilities, electric power supply and libraries. The latest national population census put the total population of Nsukka Zone at 1,377,001, with women numbering 713,286, or 51.8% of the population (National Population Commission, 2006).

The study adopted a combination of random and purposive sampling techniques. The purposive sampling technique was used to select two rural communities from each of the seven local government areas in the Nsukka Zone, generating a total of 14 communities to be studied. The 14 communities were purposively selected, based on their having all the attributes relevant to rural communities. Then a random sampling technique was used to select women who participated in the study, being a random sample of the women who attended the general meeting called for the purposes of the research. Greater percentages of the women in these areas are farmers, traders, teachers and health workers. The study surveyed 350, or about 0.05% of the women in Nsukka Zone following Nwala's (1981) specification on sampling a large population. According to Nwala, if the population is several thousand, a 5% or lower sample will be adequate. Thus, from a population of 713,286 females, 350 women were sampled, 25 women from each community under study.

The instrument for data collection was a structured questionnaire with closed-ended questions for which there were only four possible responses: strongly agree (SA), agree (A), disagree (D), strongly disagree (SD). Participants with low literacy levels were assisted in completing the questionnaire through being allowed to respond verbally to the questions (with the questions translated from English into local languages). To ensure anonymity, the questionnaire had no provision that could personally identify the respondent. Out of the 350 questionnaires distributed, 335 (96%) were returned and found valid for analysis.

The data were analysed using means and percentages in relation to the objectives of the study. The mean rating for each item number was based on a four-point scale and the mean ratings of the items were calculated.

The study adopted a Likert scale for scoring the statements according to the respondent's attitude to the statements. The decision rule was determined by a division of the sum of the Likert scales of 4, 3, 2 and 1 by the 4-point scale. That is:

$$\frac{10}{4} = 2.5 \frac{10}{4} = 2.5$$

Therefore, mean scores of 2.5 and above were regarded as positive while scores below 2.5 were treated as negative.

5. Results: ICT for reproductive health information access

As Table 1 shows, the highest proportion of women were aged between 31 and 35 years, while those within the age range of 20 to 35 constituted almost 50% of respondents. More than 57% of respondents had only primary or no formal education, indicating low literacy rates.

Table 1: Respondent demographic data (n = 335)

	Respondent profile	Number	Percentage [%]
Age range	20-30 years old	76	22.7
	31-35 years old	108	32.2
	36-45 years old	65	19.4
	46-55 years old	45	13.4
	55 years old or above	41	12.2
	Total	**335**	**100**
Educational qualification	No formal education	62	18.5
	Incomplete primary education	38	11.3
	Primary education certificate	92	27.5
	Secondary education certificates (WASC/SSC/TCII)*	81	24.2
	Tertiary education certificates (NCE/ND)**	36	10.7
	Tertiary education certificates (HND degree certificate)***	26	7.8
	Total	**335**	**100**

Marital status	Married	153	45.7
	Single	135	40.3
	Divorced	3	0.9
	Separated	2	0.6
	Widow	42	12.5
Total		**335**	**100**

**WASC =West African School Certificate; SSC = Senior School Certificate; TCII = Teacher's Grade 2 Certificate*
***NCE = National Certificate in Education; ND = National Diploma*
****HND = Higher National Diploma*

Table 2 below displays the women's responses when asked about their health information needs, indicating that the five major reproductive health information needs related to fertility; the use of contraception; abortion-related information; information on sexually-transmitted diseases; and information on managing unintended pregnancy. Information on female genital mutilation and rape-related cases had low mean scores. A possible explanation for these lower ratings is that the respondents did not feel comfortable discussing these subjects.

Table 2: Reproductive health information needs (n = 335)

Rank	Types of information needs	SA*	A	D	SD	Mean
1	Information related to infertility	180 (54%)	101 (30%)	38 (11%)	16 (5%)	3.3
2	Information on use of contraception, family planning	176 (53%)	106 (32%)	35 (10%)	18 (5%)	3.3
3	Abortion-related information	95 (28%)	190 (57%)	39 (12%)	11 (3%)	3.1
4	Information on prevention and control of sexually transmitted diseases	109 (33%)	164 (49%)	42 (12%)	20 (6%)	3.1
5	Information on managing unintended pregnancy	98 (29%)	107 (32%)	87 (26%)	43 (13%)	2.8
6	Information on antenatal and postnatal care	101 (30%)	87 (26%)	74 (22%)	73 (22%)	2.6
7	Information on managing rape-related challenges	67 (20%)	45 (13%)	167 (50%)	56 (17%)	2.4
8	Information on female genital mutilation	34 (10%)	49 (15%)	185 (55%)	67 (20%)	2.1

**SA = strongly agree (score of 4); A = Agree (3); D = Disagree (2); SD = Strongly disagree (1)*

Table 3 shows participants' responses when asked about existing governmental and non-governmental information access structures, indicating that, at a local level,

hospitals/health centres, markets, schools, churches and women's organisations were regarded as the five main information access structures for reproductive health information, followed by community-based organisations (CBOs). Libraries and information centres were not highly rated as sources of health information in the surveyed areas relative to the top five.

Table 3: Existing governmental and non-governmental information access structures (n = 335)

Rank	Existing information access structures	SA	A	D	SD	Mean
1	Hospitals/health centres	165 (49%)	158 (48%)	8 (2%)	4 (1%)	3.5
2	Markets	168 (50%)	134 (40%)	23 (7%)	10 (3%)	3.4
3	Schools	56 (17%)	67 (20%)	97 (29%)	115 (34%)	2.8
4	Churches	87 (26%)	153 (45%)	46 (14%)	49 (15%)	2.8
5	Women's organisations	96 (29)	112 (33%)	64 (19)	63 (19%)	2.7
6	Community-based organisations (CBOs)	43 (13%)	76 (22%)	167 (50%)	49 (15%)	2.3
7	Libraries and information centres	37 (11%)	66 (20%)	154 (46%)	78 (23%)	2.2
8	Banks	16 (5%)	34 (10%)	130 (39%)	155 (46%)	1.7

Table 4 below shows that, out of 15 possible health information sources, participants highlighted personal contact with friends and relatives, hospitals/health centres, churches, women's organisations, and radio and TV as the top five information sources. ICTs and ICT-enabled content (mobile and Internet communications, and social media) were noted as information sources, though they were rated comparatively low, at 8, 10 and 12 out of 15.

Table 4: Sources of reproductive health information (n = 335)

Rank	Information sources	SA	A	D	SD	Mean
1	Personal contact with friends and relations	198 (59%)	97 (29%)	39 (12%)	1 (0.2%)	3.5
2	Hospitals/health centres	201 (60%)	95 (29%)	21 (6%)	18 (5%)	3.4
3	Churches	188 (56%)	107 (32%)	30 (9%)	10 (3%)	3.4
4	Women' organisations	109 (33%)	167 (50%)	43 (13%)	16 (5%)	3.1

5	Radio and television	111 (33%)	153 (46%)	67 (20%)	4 (1%)	3.1
6	Town criers	74 (22%)	163 (49%)	82 (24%)	16 (5%)	2.9
7	Schools	87 (26%)	90 (27%)	118 (35%)	40 (12%)	2.7
8	Mobile phones (text messages/ calls)	73 (22%)	81 (24%)	132 (39%)	49 (15%)	2.5
9	Community-based organisations (CBOs)	45 (13%)	78 (23%)	186 (56%)	26 (8%)	2.4
10	Internet (via cybercafés, libraries, personal computers)	47 (14%)	86 (26%)	102 (30%)	100 (30%)	2.2
11	Newspapers, news magazines	31 (9%)	57 (17%)	174 (52%)	73 (22%)	2.1
12	Social media (e.g., Facebook, WhatsApp, Twitter)	21 (6%)	34 (10%)	230 (69%)	50 (15%)	2.1
13	Libraries and information centres	44 (13%)	42 (13%)	107 (32%)	142 (42%)	2.0
14	Workshops/seminars	12 (4%)	37 (11%)	208 (62%)	78 (23%)	1.9
15	Posters/handbills	25 (8%)	31 (9%)	154 (46%)	125 (37%)	1.9

Table 5 below shows that, when asked about challenges to access to reproductive health information, the respondents ranked lack of power supply to access electronic information from radio, TV and Internet very strongly (90% agreement), giving that challenge the same mean score (3.4) as lack of information access structures (89% agreement) and the high rate of illiteracy (88% agreement). The only challenge ranked higher was the challenge of health workers failing to organise workshops and seminars for discussion of reproductive health issues (95% agreeement, and a mean score of 3.6). Also in the top six challenges were rural women's reticence towards discussing reproductive health issues (71% agreement) and the provision of information in formats unfamiliar to rural people (67% agreement).

Table 5: Challenges of accessing reproductive health information (n = 335)

Rank	Challenges	SA	A	D	SD	Mean
1	Health workers hardly organise seminars or workshops on reproductive health	225 (67%)	95 (28%)	10 (3%)	5 (2%)	3.6
2	Lack of adequate information access structures such as libraries, hospitals, schools, etc.	193 (58%)	103 (31%)	28 (8%)	11 (3%)	3.4
3	High illiteracy rate	188 (56%)	109 (32%)	34 (11%)	4 (1%)	3.4

4	Lack of power supply to access electronic information from radio, TV and Internet	178 (53%)	124 (37%)	21 (6%)	12 (4%)	3.4
5	Much of the information appears in format strange to rural dwellers	121 (36%)	104 (31%)	67 (20%)	43 (13%)	2.9
6	Rural women shy away from discussing reproductive health issues	75 (22%)	164 (49%)	67 (20%)	29 (9%)	2.9
7	Secrecy about reproductive health information	86 (25%)	117 (35%)	73 (22%)	59 (18%)	2.7
8	Health workers shy away from discussing sexual information	41 (12%)	123 (37%)	78 (23%)	93 (28%)	2.3
9	Health workers lack the training to provide reproductive health information	12 (4%)	42 (12%)	127 (38%)	154 (46)	1.7

Table 6 below presents the respondents' ranking of various possible strategies for more efficient access to reproductive health information, indicating what rural women see to be desirable, with the highest-ranked strategies being the establishment of good information access structures in the rural areas (almost 100% agreement) and reduction of the illiteracy rate through the provision of adult education facilities (98% agreement). Provision of electricity power supply for the purpose of information access through mobile communications and the Internet (82% agreement) was also ranked in the top five strategies.

Table 6: Strategies for efficient access to reproductive health information (n = 335)

Rank	Strategies	SA	A	D	SD	Mean
1	Provision of good information access structures in the rural areas	182 (54%)	150 (45%)	2 (0.6%)	1 (0.3%)	3.5
2	Provision of adult education facilities to reduce illiteracy rate	149 (45%)	177 (53%)	8 (2%)	1 (0.3%)	3.4
3	Posting of health information extension workers in the rural areas	156 (47%)	134 (40%)	31 (9%)	14 (4%)	3.3
4	Creating greater awareness of reproductive health education	104 (31%)	194 (58%)	30 (9%)	7 (2%)	3.2
5	Provision of electric power supply in rural areas	112 (33%)	198 (59%)	18 (6%)	7 (2%)	3.2
6	Translation of existing information into local languages	66 (20%)	243 (73%)	24 (7%)	2 (0.6%)	3.1
7	Organisation of reproductive health workshops in rural area.	112 (33%)	168 (50%)	43 (13%)	12 (4%)	3.1

6. Discussion: Crossing the digital divide in rural Nsukka Zone

The five main reproductive health information subject areas prioritised by the surveyed women -- fertility, contraception, abortion, sexually-transmitted diseases, managing unintended pregnancy -- indicate key major health challenges for Nigerian women in rural Nsukka Zone in Enugu State. (The reasons for the finding of limited interest in information on rape-related issues are unclear, but the finding may have to some extent been due to the stigma associated with rape (Goutier, 1995; UN, 1996). Also unclear are the reasons why the majority of the respondents did not express a need for information on female genital mutilation.)

Two key findings were that: libraries and information centres were not ranked in the top five information access structures (Table 3) available in rural Nsukka Zone; and that among ICT platorms and ICT-delivered content, only the radio and TV category (and not the mobile telephony, Internet, or social media categories) was ranked in the top five information sources (Table 4).

The findings reveal that, in the year of study (2015), a number of issues were combining to limit the surveyed women's access to reproductive health information. The dearth of libraries and information centres; the limited availability of mobile phones, Internet and social media; and the limitations of power supply to access information from radio, TV and the Internet on an ongoing basis, mitigate against the empowerment of women with respect to access to reproductive health information -- at a time when information and electricity are available as basic infrastructures and services in almost all cities and towns across Nigeria, but not in rural villages.

At the same time, it is notable that, despite the limitations of mobile and Internet communications and of power supply, nearly half (46%) of the respondents agtreed that mobile phones, via texts and calls, were a source of reproductive health information. This finding corresponds with the findings of earlier studies (Akinfaderin-Agarau et al., 2012; Egbula, Agwu, & Uzokwe, 2013; Lester et al., 2010), representing an emergent dynamic in health information delivery in Nigerian rural communities. The finding, coupled with the available litrature, suggests that health workers and information extension officers in the rural areas of Nigeria should seek to exploit mobile communications more extensively for reproductive health purposes.

Another significant finding was that many of the surveyed women saw unfamiliar information formats for health information as an access challenge. This finding, coupled with findings in the extant literature (Amadi, 1981; Ezema, 2011), suggests the need for content repackaging in local languages and in non-textual oral and visual forms such as videos, radio and television in order to achieve wider access. While the preferred strategy of respondents for efficient access to reproductive health information (Table 6) was information access structures (e.g., libraries and information centres), just as important, in my analysis, will be the empowerment

of rural women through a combination of: education for advanced literacy (as highlighted by the studies of Ransome-Kuti (1991) and Tinker et al. (1994)); and information provision through mobile communications, including a mix of textual, audio and visual content formats and using the local languages of targetted rural dwellers.

7. Conclusion: Slow move towards mobile, investment needed in Internet

A history of reliance on oral sources of reproductive health information is slowly changing in rural Nsukka Zone. As the use of mobile telephony in accessing reproductive health information is evolving, as reflected in the findings, this evolution requires further investigation. Simultaneously, ICT infrastructure investment and basic mobile government communications are required in rural villages. Government should train health information extension workers, posted in rural communities, in the provision of health information to rural dwellers, via mobile phone communications. Since power supply is critical to effective information dissemination, particularly through electronic media, government and communities should also puruse rural electrification, which can use simple, low-cost solar infrastructure.

In addition, government should embark on providing basic information access structures, such as libraries with Internet hubs, that will improve access to reproductive health information. Such development can be based on counterpart funding, where the rural communities provide some small proportion of the funds. The aim should be to introduce library and information centres in every community. Library associations and other information professionals should mount advocacy campaigns in the communities and in government circles, and should sponsor bills in the states and in the National Assembly for provision of modern library and Internet facilities in rural communities.

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QoS Performance Analysis of Bit Rate Video Streaming in Next Generation Networks Using TCP, UDP and a TCP+UDP Hybrid

Xolani Dlamini
Postgraduate Student, Department of Computer Science, North West University Mahikeng Campus, South Africa

Francis L. Lugayizi
Postgraduate Student, Department of Computer Science, North West University Mahikeng Campus, South Africa

Bukohwo M. Esiefarienrhe
Associate Professor, Department of Computer Science, North West University Mahikeng Campus, South Africa

Abstract
The growth in users streaming videos on the Internet has led to increased demand for improved video quality and reception. In next generation networks (NGNs), such as 3G and 4G LTE, quality of service (QoS) implementation is one of the ways in which good video quality and good video reception can be achieved. QoS mainly involves following an industry-wide set of standard metrics and mechanisms to achieve high-quality network performance in respect of video streaming. Adopting routing and communication protocols is one way QoS is implemented in NGNs. This article describes QoS of bit rate video streaming, and QoS performance analysis of video streaming, in relation to the main network transport protocols, namely transmission control protocol (TCP) and user datagram protocol (UDP). A simulation test bed was set up using OPNET modeller 14.5. In this setup, a network topology was created and duplicated three times, in order to configure two simulation scenarios (each using the distinct protocols), and a third simulation scenario using both protocols in hybrid form. The findings in the simulations indicated that, when a network is configured with both TCP and UDP protocols in video streaming, there is a positive change in the degree of performance in terms of the QoS of video-streaming applications, unlike when the protocols are used independently.

Keywords
quality of service (QoS), bit rate video streaming, QoS routing, transmission control protocol (TCP), user datagram protocol (UDP)

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1. Introduction

Next generation networks (NGNs) evolved from packet-switched networks that use Internet Protocol (IP) at the network layer (Knightson, Morita, & Towle, 2005). NGNs can either be wireless, such as for mobile phones, or wired, such as for desktops. A variety of applications make use of these networks, one of which is video streaming. Monitoring the performance of video streaming is considered one of the most challenging problems in NGNs (Adibi, Jain, Parekh, & Tofighbakhsh, 2010), requiring continual research and development. Quality of service (QoS) implementation and monitoring is one amongst many approaches that seek to evaluate the performance of video-streaming applications in NGNs. As more multimedia applications are developed and deployed onto these networks, it has become necessary to introduce more advanced mechanisms to monitor the performance of these applications, in order to achieve user satisfaction. Such mechanisms need to be able to enhance QoS in both legacy and concurrent NGNs, so to be able to meet user demand.

In this article, we describe QoS of bit rate video streaming, and then present a QoS performance analysis of video streaming in relation to the main network transport protocols, namely transmission control protocol (TCP) and user datagram protocol (UDP). The main research question we seek to answer is as follows: Is QoS evaluation a reasonable way to address performance challenges in bit rate video streaming in NGNs?

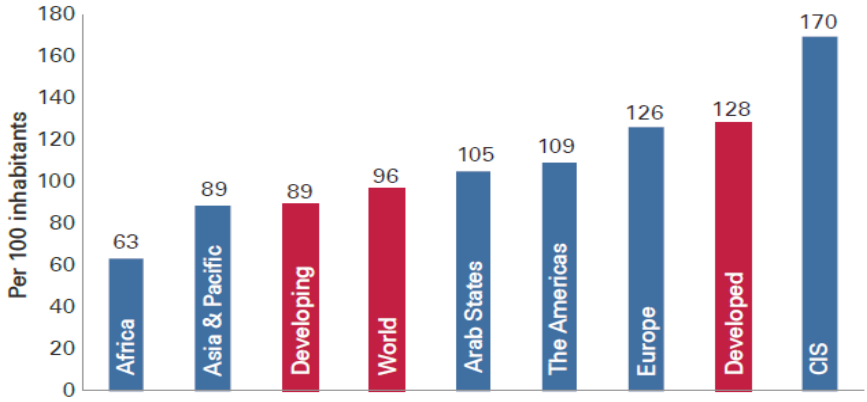
2. Background: QoS, TCP, UDP, bit rate video streaming

Mobile data traffic, namely for Internet access and video communication, increased three-fold every year in the 10 years between 2001 to 2010, and the demand for using mobile devices was seen to expand beyond 4.5 billion users (Cisco, 2010). By 2016, it was estimated that mobile data traffic had grown 4,000-fold over the previous 10 years, and that global mobile devices and connections had reached an estimated 7.9 billion in 2015 (Cisco, 2016). Video streaming, online games and IPTV are examples of the rapidly increasing need for real-time multimedia services. Furthermore, mobile ad hoc networks have grown abundantly in popularity, while the combination of mobile telecommunication networks with Internet continues to evolve in an innovative manner, via what are now termed next generation mobile networks (NGMNs) (Adibi et al., 2010). Evidence from the telecommunications industry (Tappayuthpijarn, Liebl, Stockhammer, & Steinbach, 2009) shows that NGMNs present a major advantage for operating networks, given the increase in digital traffic (Mok, Chan, & Chang, 2011). Some research shows that mobile videos will cause mobile data traffic to rise by more than 66%, expanding possibly 39 times, in the five years 2014 to 2019 (Freris, Hsu, Singh, & Zhu, 2013).

Figure 1 shows mobile growth around the world, which is challenging systems' capability and clients' connectivity. Increased mobile data traffic means increased

demand for QoS, for satisfactory user experience. QoS prioritises one type of traffic over another, helping to resolve data congestion in NGMNs.

Figure 1: International mobile growth



Source: Sanou (2013)

To meet an acceptable video quality, there is a need for a minimum bit rate. The bit rate measures how much data is being transmitted in a given peroiod of time, and the increased QoS demands can only be maintained if the required bit rates and delays are not too challenging (Ramanathan, 2005). Using multiple access networks to connect users to streaming servers is one of the techniques used to gain improved streaming quality. Two transport protocols dominate research discussions on streaming quality, namely TCP and UDP.

Parziale et al. (2006) present a summary of the invention of TCP, and explain how to create reliable, client-to-client transmission of data on a network. Previously TCP was considered as inadequate for video streaming. However, this has changed because it is now implemented with HTTP (Tappayuthpijarn, et al., 2009). TCP is the dominant protocol for high traffic volumes, and it promotes fairness between data transfers by evenly sharing the available bandwidth between users.

Unlike TCP, which is connection-oriented and involves "handshaking" between the network and devices, UDP is not connection-oriented and does not use handshaking dialogues. With UDP, there is no guaranteed delivery, meaning there is no repetition and ordering. Since UDP has no handshaking, it uses a normal model of transmission. For presenting functions that are different to source and destination of a datagram,

UDP only offers techniques for verification of data integrity. Accordingly, UDP has the following challenges: (i) it does not offer verification sequencing for datagrams; and (ii) it excludes connected datagram services. Therefore, it is important to note that source hosts that require consistent communication should use TCP (or a programme of similar reliabilty), which can provide own sequencing and acknowledge services (Zheng & Boyce, 2001), rather thatn useing UDP. This recommendation becomes a critical requirement in mobile video streaming applications within NGNs, especially when video streaming is of a real-time nature.

QoS measures

QoS is the process the network provider implements to deliver a satisfactory service, and with an assured level of service. To achieve this, QoS has to be measured. The main attributes that the metrics of QoS should always have are *timeliness*, *precision* and *accuracy* (Fiedler, Hossfeld, & Tran-Gia). *Timeliness* is the time taken to produce the result of the process. The number of results produced is measured by *precision*. The correctness of the results produced is a measure of *accuracy*.

In their work on QoS of computer networks and QoS measures, Mohapatra, Li, and Gui (2003) recommend that a few key QoS metrics are used to measure network end-to-end performance in relation to user requirements:

- ***Packet end-to-end delay:*** This refers to the elapsed time it takes for a packet to traverse from source, through the network, to its destination, and is measured in seconds. This is also referred to simply as end-to-end delay.
- ***Packet-delay variation (jitter):*** Whenever the end-to-end delay varies in a network, especially in video streaming, it is referred to as packet delay variation or jitter, measured in seconds.
- ***Bandwidth:*** Bandwidth refers to the highest rate of data transfer that a communication channel or link can sustain between a source and destination network. The difference between traffic sent and traffic received assists in determining the bandwidth available and in the long run, the point-to-point throughput of a channel. Traffic sent and received is measured in packets per second, while throughput is measured in bits per second.
- ***Packet loss (IP traffic dropped):*** This refers to a situation where a network loses data packets, especially where they fail to reach their destination network and is also referred to as IP traffic dropped. This is measured in packets per second.

QoS measures are generally implemented in video processing applications, due to the fact that video streaming is associated with constant delay requirements – and sometimes low bandwidth – and thus needs QoS interventions to provide quality.

QoS routing

QoS measures can be implemented through QoS routing, which is one of the driving forces behind video streaming applications. The main aim of QoS routing is to find

a path in a network that satisfies the given QoS limitations, such as energy, end-to-end delay and bandwidth availability. QoS routing is a scheme that takes into consideration the appropriate information about each link. Based on that information, it selects paths that satisfy the QoS requirements of a particular data flow (Asokan, 2010). Leela, Thanulekshmi, and Selvakumar (2011) state that the issue of QoS routing is crucial for dispersed applications, such as distributed games and Internet-enabled cellular phones. These dispersed applications place many different potential constraints on the aforementeiond QoS elements: *packet end-to-end delay, packet-delay variation* (*jitter)*, *bandwidth,* and *packet loss (IP traffic dropped)*. With QoS routing, the properties used to determine that one route is more appropriate than another are decided according to the QoS parameters. Routing in networks can either be *unicast* or *multicast*, as outlined below.

Unicast routing
The main feature of this routing algorithm is that it is used to connect only two nodes, namely a source and a destination, using a path that visits nodes in a predetermined way that corresponds to the location of routers (Dorigo & Stützle, 2003). Unicast is particularly efficient when video content delivery is among a group of limited users and using the point-to-point method. In unicast, a separate connection is created for each user, meaning resources are only used when the user of that given connection is active (Oyman, Foerster, Tcha, & Lee, 2010; Zhang & Wien, 2011). Typically, one of three main alternatives is used for the implementation of unicast routing: flooding, distance-vector routing, and link-state routing.

Multicast routing
In multicast routing, the algorithm simply states that one sender can send data to more than one recipient, and only one copy of the data is sent. Guo and Yang (2008) generated the idea of achieving the longest lifetime in mobile networks through two widely dispersed multicast routing algorithms. Multicasting is suitable for large numbers of users, as it can give good service even with large numbers of users streaming videos using mobile devices. (A routing mode is a single set of paths for sources and destinations in old networks, normally in the process of multicast routing.)

We now turn to a discussion of bit rate video streaming.

Bit rate video streaming
The volume of video traffic is expected to double annually in the coming years and, accordingly, to account for the dominant share of wireline and wireless Internet traffic (Cisco, 2010; 2016). In the past decade, various authors have reviewed the major topics in video streaming, such as scalable codecs, design of transport protocols, and adaptation techniques (see, for example, De Cicco, Mascolo, & Palmisano, 2011). Video streaming can be divided into two types: (i) live, real-time streaming,

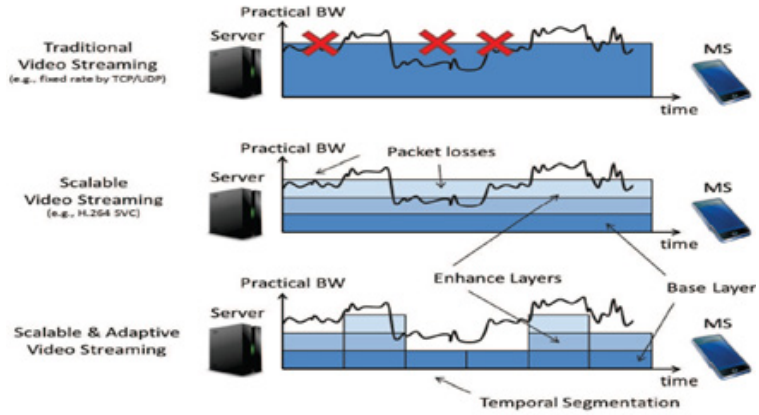
which is focused on encoding after capturing; and (ii) archived streaming, based on pre-encoding and storing for later viewing. Video conferencing applications, videophones, and interactive games are some of the examples of live, real-time video streaming. All these applications have strict delay requirements (Ji, 2009). Wireless networks are charactreised by a high bit error rate (BER) and frequent changes in channel quality (Fehér & Oláh, 2008; Tsai, Chilamkurti, Park, & Shieh, 2010), both of which are harmful to video communication, i.e., treaming quality can be harmed if the receiver tries to recreate the structure of the video from data characterised by errors. Thus the job of avoiding channel errors is central to QoS in video streaming over wireless networks.

Video codecs are designed to work at variable bit rate, i.e., a bit rate adjustable over long time scales by the video server. However, if the instantaneous wireless channel quality cannot support that bit rate (i.e., can deliver that bit rate only with a greater BER), video performance suffers dramatically (Aditya & Katti, 2011). Accordingly, variable bit rate encoding assigns more bits to complicated structures and fewer bits to less complicated structures, thus providing high video quality (Tabrizi, Peters, & Hefeeda, 2013). MPEG-4 is a compressing method in which the codec converts video traffic from low bit rate to high bit rate (see Memon, Hassan, & Memon, 2014). All multimedia traffic or video streaming has its own limitations that contradict the workflow of real-time protocols. For instance, multimedia traffic is a variable bit rate traffic origin, while the real-time networks are normally constant bit rate (CBR) channels, meaning that the amount of output of data per segment varies in multimedia traffic as opposed to real-time networks with a constant bit rate (Silvestre-Blanes, Almeida, Marau, & Pedreiras, 2011).

Some researchers have suggested use of context delivery networks (CDNs) as a streaming model. CDNs spread live or non-live video to users, i.e., before beginning a video streaming session (in a non-live setting), the source server can disperse a video to various assisted servers (Cisco, 2010; Nguyen, Nguyen, & Cheung, 2010). In order to view the video, the user then connects a few of these assisted servers in parallel.

Other bit rate approaches are scalable, and scalable and adaptive, video streaming. Figure 2 presents a comparison of traditional video streaming with scalable, and scalable and adaptive, methods (Chen, 2012). Alteration of link quality causes old video streams with fixed bit rates to fail to adapt to the changes, leading to packet loss and frequent termination of video streaming if the maintainable link bandwidth varies substantially a certain bit rate.

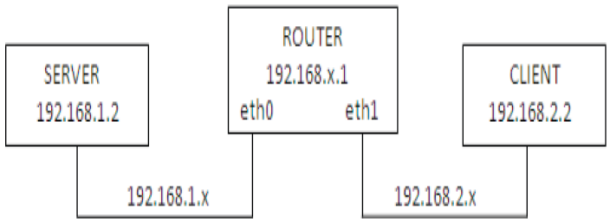
Figure 2: Traditional, scalable, and scalable and adaptive, video streaming



Source: Chen (2012)

Figure 3 shows a test setup used in Gürler and Bağci (2010). In this setup, the authors propose that content be streamed over managed local area networks (LANs), whereby the channel space available is randomly altered and impermanent introduction of the packets results in an additional 1% packet loss.

Figure 3: Network structures



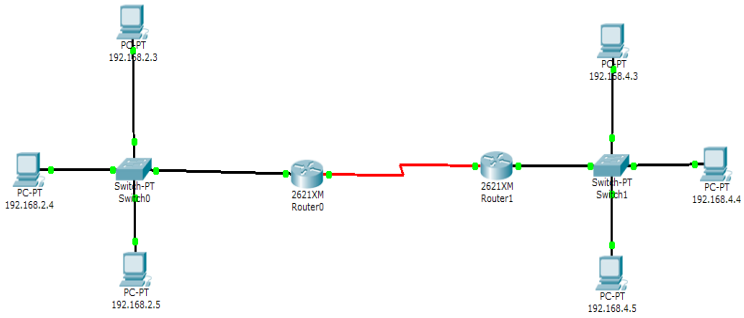
Source: Gürler and Bağci (2010)

By using video bit rate adaptation, the video quality can also be made fit for wireless networks. Khan, Sun, Jammeh and Ifeachor (2010) present a quality of experience-based model that can assist in adjusting the sending bit rate according to the supplied content. The quality of an output video sequence is evaluated by adopting

an evaluation model of video quality, which is defined by the number of decodable frames over the total number of frames originally sent from the video source (Lin, Ke, Shieh, & Chilamkurti, 2006).

As stated above, the protocols we used in our simulations in the test bed environment for QoS were TCP and UDP. Figure 4 shows a network that was designed on packet tracer, which uses the same transport protocols that were used in the test bed environment. As explained earlier, TCP is the more complex of the two protocols.

Figure 4: Sample network topology that uses transport protocols to transmit data



TCP is valued for its ability to open the shortest path first; to add reliability with retransmissions and ordering; and to offer fair bandwidth-sharing through congestion control. However, while TCP provides both reliability and ordering, and prevents congestion by controlling transmission rates, it is not optimised for video streaming (Lindeberg, Kristiansen, Plagemann, & Goebel, 2011). The TCP protocol is designed for wired networks and is not efficient for wireless networks. It reduces the transmission rate when there is a packet loss, which generates significant performance degradation in wireless networks because wireless channels generates high bit error rates. Source for TCP data maintains two "windows": a receive window for each destination, representing the available buffer capacity of each destination; and a "congestion window", representing the available capacity of the network. As the source transmits data, the size of each window is reduced by an amount equal to the size of the data sent (Shah & Patel, 2014).

UDP, the other dominant protocol in the computer networks environment, provides for less delay, but it increases packet loss because it has no network congestion avoidance mechanism.

TCP and UDP provide basic transport functions, while real-time transport protocol (RTP) and RTP control protocol (RTCP) run on top of TCP/UDP. UDP does not perform bandwidth adaptation or guarantee packet delivery, but it transmits the same bit rate as forwarded by the application (Hossfeld, Schatz, & Krieger, 2014). UDP is typically used by programmes that transmit small amounts of data at a time, or that have real-time requirements. In real-time situations, the low overhead and multicasting capabilities of UDP (for example, one datagram, many recipients) are better-suited than TCP.

This background discussion of QoS, QoS routing, and bit rate video streaming, has set the scene for presenting the experiment we conducted.

3. Test bed experimental setup and implementation

Our simulation consisted of testing three different routing protocols. The OPNET modeller 14.5 tool was used for the simulation, because it has the ability to generate accurate results for test scenarios via modelling traffic selection, projection and statistical data analysis, all of which require simulation. With its ability to enable designers to design either a small or large complex network, OPNET is a relatively powerful simulation software.

The network topology for the simulation was created in such a way that the two transport protocols (TCP and UDP) could be implemented. The sample applications used to generate video streaming traffic were a video conferencing application and a file transfer protocol (FTP) application. Since the focus of the experiment was on bit rate video streaming, the video conferencing application was set with a high-resolution video, because users have come to expect high resolution when streaming online videos. We ran all the simulations on Windows 7.0 Professional platform on a desktop with 3.40 GHz, 4.00GB RAM and a 32-bit operating system. Table 1 summarises the three scenarios created in the simulation test bed.

Table 1: Network simulation scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**
Protocol	TCP	UDP	TCP+UDP
Application	Video	Video	Video
Application	FTP	FTP	FTP

The hybrid TCP+UDP arrangement was set up so that the advantages of each protocol could compensate for their respective disadvantages.

4. Results and discussion

This section presents the results of our simulations, and discussion of the QoS parameters – end-to-end delay; jitter; bandwidth, and IP traffic dropped – that were selected for the test bed experiment and used in the simulation to determine which of the two protocols (TCP and UDP) performed better in terms of video streaming, – or whether the third scenario using a hybrid of TCP and UDP performed better than either of the two protocols alone.

Packet end-to-end delay

Packet end-to-end delay is the time it takes for a packet to be transmitted across a network from source to destination. Statistics for packet end-to-end delay were selected for video conferencing before simulation and are displayed in Figure 5 below. End-to-end delay wwas calculated using this equation (1):

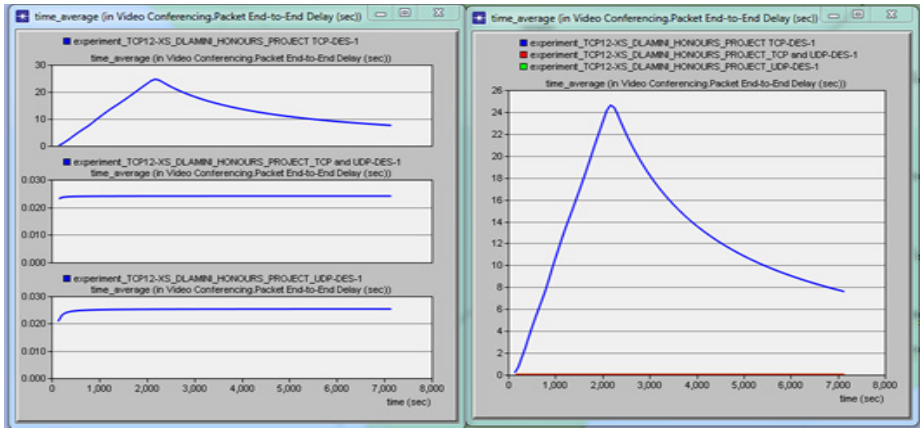
Dend_end = N (dtrans + dprop + dproc) (1)

(where dtrans is the transmission delay, dprop is the propagation delay, dproc is the processing delay, N is the number of links or routers, and Dend_end is the end-to-end delay)

In the simulation results shown in Figure 5 below, the TCP scenario is seen to have had the highest average time of packet end-to-end delay. The TCP three-way handshake characteristic clarifies the way TCP sends data, which may also cause delays if the destination takes time to acknowledge the source from which it received the sent information.

The UDP and TCP+UDP scenarios had equal amounts of packet end-to-end delay, and significantly less than in the TCP scenario. Unlike TCP, UDP does not guarantee packet delivery and does not establish a close connection, which causes its end-to-end delay readings to be low. In conclusion, the hybrid scenario was seen to be the best scenario for reducing packet end-to-end delay in streaming video on an NGN.

Figure 5: Packet end-to-end delay

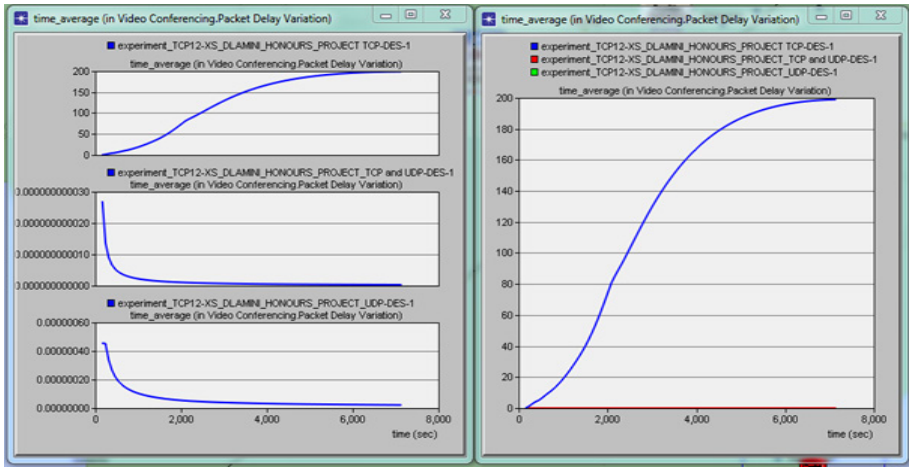


Note: *The red line of the TCP and UDP hybrid experiment is superimposed on the green line of the UDP experiment because the results have substantially similar values.*

Packet-delay variation (jitter)

Figure 6 below shows the different amounts of packet-delay variation that was noted during the simulation in each of the three scenarios. This variance in end-to-end delay for video packets and was measured from the time when a packet was created to the time when it was received.

Figure 6: Packet-delay variation (jitter)



Note: The red line of the TCP and UDP hybrid experiment is superimposed on the green line of the UDP experiment, because the results have substantially similar values.

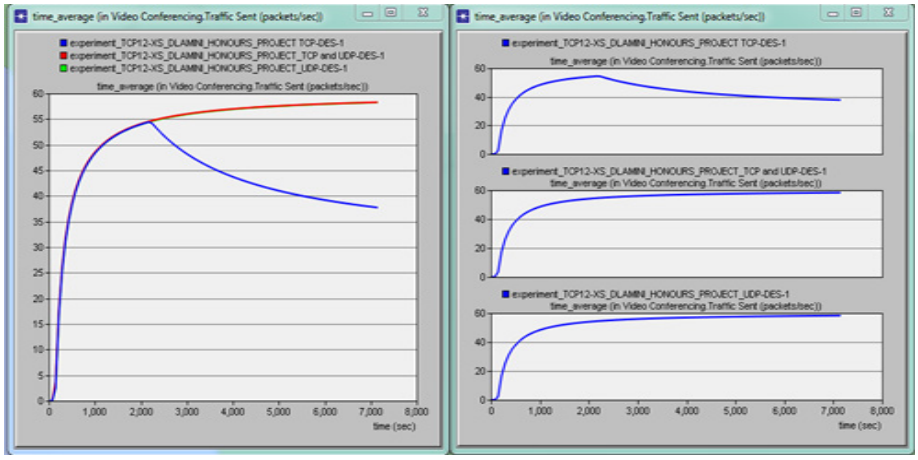
Packet-delay variation is the difference in end-to-end, one-way delay between selected packets in a flow, with any lost packets being ignored. Since this simulation concentrated on video streaming, packet delay was often present. Looking at the results, the TCP, UDP and TCP+UDP scenarios all improved packet delay. (Packet delay can be caused by having multiple hops. The experimental network topology had few hops, which could have caused the improvement in the three scenarios.)
The TCP scenario provided the best performance, generating less jitter than the UDP or TCP-UDP scenarios.

Bandwidth: Traffic sent

Traffic generated by each application was described in the "application definition" block of the OPNET modeller and since this work focused on video streaming, the video conferencing application was used. Traffic sent is the average number of packets per second submitted to the transport layer by, in this case, all video conferencing applications in the network.

Figure 7 below shows the results for the "traffic sent" statistics that were collected during the simulation. As the video conferencing application was the major source of traffic and video was accessed from the video-streaming servers, best-effort type-of-service and a frame size of 128 x 240 pixels were used.

Figure 7: Traffic sent



Note: The red line of the TCP and UDP hybrid experiment is superimposed on the green line of the UDP experiment, because the results have substantially similar values.

In Figure 7, the x-axis represents time in seconds and the y-axis represents the number of packets. The results were presented in a stacked (right-hand-side of figure) and

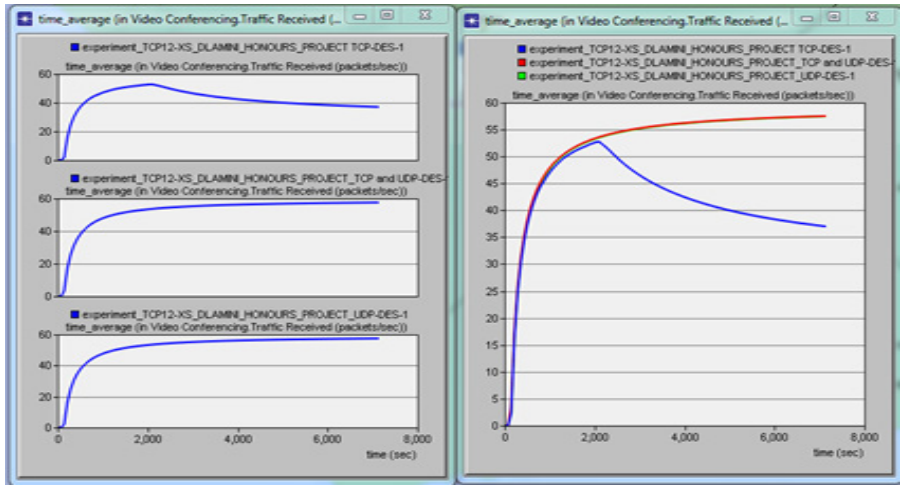
overlaid (left-hand-side of figure) form, so as to clearly display the differences across the three scenarios relative to the amount of traffic sent. The TCP simulation is represented in the topmost graph on the right of Figure 7, while the hybrid scenario is the middle graph and the UDP scenario is the bottom graph.

The downward slope of the curve in Figure 7 represents a drop in packets sent, which was a function of TCP, only noticeable from 2,300 seconds of simulation onwards. It is clear from these graphs that the weakest protocol, using the amount-of-packets-sent criterion, was TCP. Meawnhile, UDP and the hybrid TCP+UDP sent equal amounts of traffic and outperformed the TCP in terms of this criterion. As shown in Figure 7, the total number of packets transmitted by UDP and the hybrid TCP+UDP was 57.5 packets per second, while the total number of packets transmitted by TCP was 37.5 packets per second. For this criterion, it is thus better to use UDP alone than to use the hybrid approach, because no advantage is gained from the hybrid effort.

Bandwidth: Traffic received

Figure 8 below shows the amount of traffic received in the simulation experiments, where in each scenario the an equal amount of traffic was received and sent.

Figure 8: Traffic received



Note: The red line of the TCP and UDP hybrid experiment is superimposed on the green line of he UDP experiment, because the results have substantially similar values.

Traffic received in this simulation was the average number of packets per second forwarded to the video conferencing applications by the transport layers in the network. Figure 8 shows that there was very little if any difference in traffic received

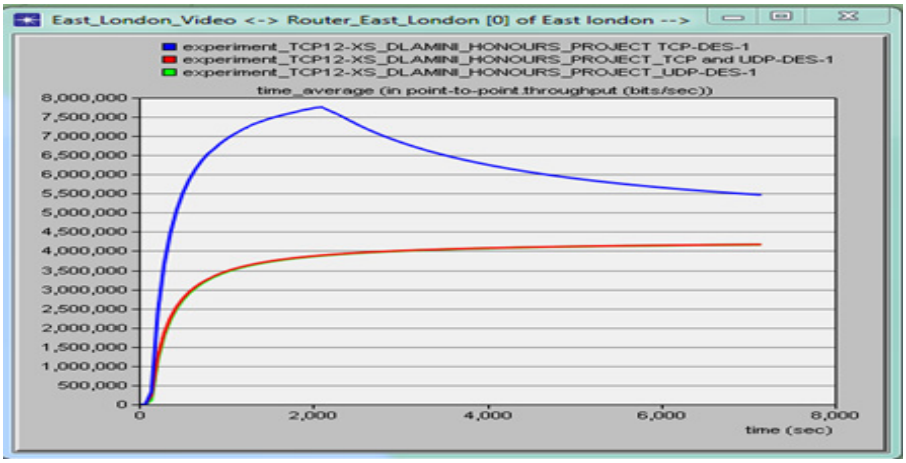
compared to traffic sent, in all three scenarios after 2,300 seconds has elapsed, though the UDP and hybrid scenarios received more traffic than the TCP scenario. The numbers of packets are presented on the y-axis against time on the x-axis.

In this study, our expectation was that the highest amount of traffic would be received when the TCP+UDP protocol hybrid was present. The average highest traffic amount in all scenarios was 57.5 packets per second, when the simulation was run for 7,200 seconds. These results show the rapid increase in the rate of traffic received, which necessitated an increase in the simulation time to two hours for better and more accurate results. At the end of the two-hour experiment, it was concluded that the traffic received in the UDP and hybrid scenarios showed better performance than in the TCP scenario. It was difficult to distinguish between performances in the UDP and hybrid scenarios, and thus we favour the UDP scenario because it did not require the additional effort for hybridising.

Bandwidth: Point-to-point throughput

Point-to-point throughput shows the time in relation to the average number of packets successfully received. Due to the fact that the work focused on bit rate, throughput was measured in bits per second. As can be seen in Figure 9, the results collected for all three scenarios were based on running the simulation for 7,200 seconds.

Figure 9: Point-to-point throughput



Note: The red line of the TCP and UDP hybrid experiment is superimposed on the green line of theUDP experiment, because the results have substantially similar values.

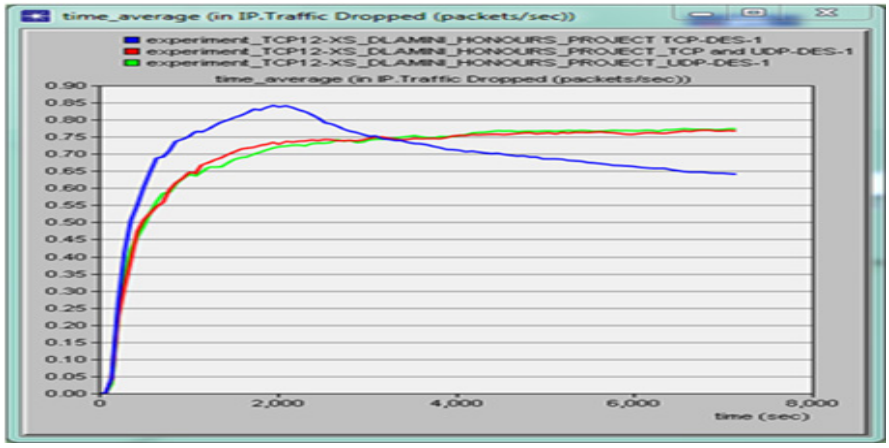
Point-to-point throughput is the average number of bits successfully received or transmitted by the receiver or transmitter channel per unit of time, in bits per second, which can also be referred to as the average rate of successful streamed videos from the servers to the clients in our network topology. The best throughput was found in the TCP scenario, followed by the TCP+UDP hybrid scenario, very closely followed by the UDP scenario.

(During the simulation process, the hybrid scenario was expected to have the highest point-to-point throughput, since it was using the features of both protocols. But in the results for the first QoS criterion (see Figure 5 on packet end-to-end delay), the TCP scenario had the highest end-to-end delay, which also influenced the high amount of point-to-point throughput in the same scenario.) Our findings thus suggest that configuring TCP is the best choice for video conferencing applications.

Packet loss (IP traffic dropped)

The IP traffic dropped statistic was chosen before running the simulations, so as to be able to compare the amount of traffic dropped across the TCP, UDP and TCP+UDP scenarios. Figure 10 below shows the data collected, measured in packets per second.

Figure 10: Packet loss (IP traffic dropped) in packets per second



IP traffic dropped is the number of IP datagrams dropped by all nodes in the network, across all IP interfaces. Handling traffic that enters a network can be carried out by controlling busy traffic and making sure that designated traffic flows get the correct bandwidth. This can often mean cutting off the excess flows, or changing the

precedence of the packets that exceed the bandwidth.

Traffic drops cause TCP to resend the packets, and Figure 10 shows that in the TCP scenario there was less packet loss than in the other two scenarios over 7,200 seconds. TCP also reduces the congestion window when it experiences great loss of packets. In all three scenarios, very few packets were lost at the beginning of the simulation, and the highest amount of IP traffic dropped in the TCP scenario was 0.84 packets per second, while the highest amount of IP traffic dropped in the TCP+UDP scenario was 0.76 packets per second.

Table 2 summarises the results obtained across the three scenarios.

Table 2: Results from the three scenarios

Video Conferencing	Statistics collected	Scenario 1 (TCP)	Scenario 2 (UDP)	Scenario 3 (TCP+UDP)
	Packet end-to-end delay (seconds)	25	0.025	0.025
	Packet-delay variation (jitter) (seconds)	200	0.000000045	0.000000000029
	Bandwidth: Traffic sent (packets/sec)	54	57.5	57.5
	Bandwidth: Traffic received (packets/sec)	54	57.5	57.5
	Bandwidth: Point-to-point throughput (bits/sec)	7,750,000	3,750,000	3,750,000
	Packet loss (IP traffic dropped) (packet loss/sec)	0.84	0.77	0.76

5. Conclusion

In this study, the main goal was to evaluate QoS, using TCP and UDP bit rate video streaming in NGNs, with the focus on the performance of the two transport protocols used. We started by first studying the challenges faced by NGNs and the benefits of using TCP and UDP when streaming videos. Secondly, we developed a framework imitating a real world network topology, where the implementation of the two transport protocols was carried out. Using the OPNET 14.5 modeller tool, we created three scenarios: one using TCP, the second using UDP, and the third using a hybrid of the two protocols.

We can categorically state that the key issue related to streaming videos online is bandwidth, which affects the streaming throughput and also network congestion. TCP is known to detect packet loss and when it is detected, TCP decreases the

congestion window and unnecessarily takes bandwidth from the competing traffic. However, use of a TCP+UDP hybrid enables more effective QoS, since UDP does not have the window congestion control capability.

Sent and received traffic were identical in all three scenarios. In the UDP scenario results, packet end-to-end delay and packet-delay variation (jitter) were low, while the TCP scenario presented the highest rate of throughput in bits per second. We conclude that, if a researcher or network administrator is concerned with high throughput when streaming videos, then TCP performs better than eith UDP or a TCP+UDP hybrid in delivery of efficient and effective network QoS.

6. Future work

In the literature review, we found that the number of mobile users streaming videos online has greatly increased. Accordingly, we now intend to extend our simulation by implementing the protocols TCP and UDP on a network congested with numerous mobile devices, and then examine QoS metrics. Moreover, we are interested in implementing this kind of QoS evaluation for streaming of live videos from different sources.

Finally, more work needs to be done on implementing these transport protocols on WiMAX technologies, which provide the same bandwidth as other wireless broadband NGNs but over longer distances with less interference.

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THEMATIC REPORT

Cyber Warfare: African Research Must Address Emerging Reality

Uche M. Mbanaso
Director, Centre for Cyberspace Studies, Nasarawa State University, Keffi, Nigeria

Abstract
This thematic report sets out the case for why studies in cyber security and cyber conflict need to be prominent in the African digital transformation research agenda.

Keywords
cyberspace, cyber attacks, cyber conflict, cyber warfare, Africa

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Cyberspace is emerging as a new battlefield, as cyber attacks can now complement state conflicts. The recent cyber feud between the US and Russia, in which the former openly accused the latter of deliberate and orchestrated hacking activities to undermine the integrity of the just-concluded US presidential election, did not come as a surprise. As we witness traditional activities increasingly shifting to this new domain, cyberspace is becoming a focal point not only for beneficial innovations, enterprises and social networking, but also a site for criminality and warfare (Ackerman, 2016; Lewis, 2011). These latter features are reshaping and redefining the digital space as an environment not only for progress and prosperity, but also for cyber threats. Meanwhile, many countries, especially in Africa, are embracing emerging trends in cyber space with little insight as to where certain of the trends may lead. The question is: In Africa, how aware are we of cyber conflicts and the possible magnitude of cyber warfare?

Unlike a decade ago, cyber warfare is no longer a strange or mystifying notion. With the emerging reality of nation-state-supported attacks on the digital infrastructure of other nations, the entrenchment of the relatively new phenomenon of cyber warfare in the human lexicon cannot be contested. Like any new concept, there is no agreed definition of cyber warfare (Applegate, 2011). As a basis for this discussion, we define cyber warfare as cyberspace-based conspiracy and conflict, usually including politically-motivated attacks on information systems and networks, targeted at a nation or nations (Betz & Stevens, 2011; Capaccio, 2012). It is a deliberate action by a nation state (or nation states), or by an organised group (or groups), against a state (or states) that is aimed at disrupting or harming critical national infrastructure (CNI) in ways that can bring the infrastructure to a standstill (O'Connell, 2012).

Cyberspace has evolved into a critical domain that countries can no longer take with levity, and that many countries are working hard to control and/or dominate. Besides the threats from financial fraudsters or groups, there are deliberate efforts by nation states to dominate and show supremacy over other states' information spaces, with the potential to negatively impact economic, political or military activities. Cyber warfare from this perspective is, perhaps, an extension of the shared notion of conspiracy and sabotage between and among nations that one finds in conventional battles (Betz & Stevens, 2011).

In cyberspace, which is intrinsically challenged by uncertainties, nation state actors are increasingly dissatisfied with building defensive strategies alone, and are working to build offensive capabilities that can assail their adversaries when desired (Capaccio, 2012, Bamford, 2013). Cyber war is part of an underground and obscure arms race, where nations invest billions of dollars to establish digital armies and stocks of digital weapons – for example malicious software codes that are politically motivated, as exemplified by the Stuxnet worm that disrupted and disabled the centrifugal equipment of an Iranian nuclear facility (Langner, 2013). Exacerbating the potential

dangers of cyber warfare is the fact that no individual, organisation or government can provide an accurate profile of the vulnerability, threat and risk landscapes evolving in, and emanating from, cyberspace (Mbanaso & Dandaura, 2015; Parks & Duggan, 2011).

What may now be considered historic examples of cyber warfare include the assault, allegedly by Russia, on the Baltic state of Estonia in 2007 (BBC, 2007), which disrupted civilian services. The attacks, which disrupted public web resources, including the Estonian Parliament, banks, ministries, newspapers and broadcasters, was allegedly prompted by a feud regarding the relocation of the Bronze Soldier of Tallinn (The Economist, 2010). This attack, which was the first known cyber attack of such magnitude targeted at a nation state, and which used the distributed denial of service (DDoS) method, sparked worldwide concern. The cyber attack on an Iranian nuclear facility in 2010, suspected to have been carried out jointly by the US and Israel (Langner, 2013), and various attacks on US interests, allegedly by China and North Korea (Perlrothoct, 2012), are other prominent examples of cyber attack exploits. (Much earlier in cyber history, many years before the public Internet, there were alleged cyber attacks on the US National Aeronautics and Space Administration (NASA) network, using the WANK worm in 1989, to protest against nuclear programmes (Applegate, 2011)).

The aftermath of the attack on the 2010 Iranian nuclear facility brought a ferocious response from the Iranian state (Perlrothoct, 2012). Iran launched its cyber counter-offensive against Saudi Arabia and Qatar, as well as American networks. Having boasted of possessing a strong cyber army, Iran carried out these attacks on perceived adversaries to buttress a point (Perlrothoct, 2012).

The December 2014 attack on Sony Pictures Entertainment, allegedly committed by North Korea, was of a magnitude capable of provoking a cyber war. The perpetuators of the Sony assault revealed embarrassing documents, whereby sensitive private and personal information of employees of Sony, amongst other critical data, was compromised. The Sony attack raised public uproar in the US, and the US government was clearly perturbed by the incident. North Korea, undoubtedly a strong aggressor in cyberspace, has continued to assemble a sophisticated cyber army for its offensive and defensive strategies (Kwark, 2015). In a similar vein, China has, undeniably, repeatedly invaded US cyberspace, exploiting vulnerabilities in certain military and government information systems and networks (Capaccio, 2012). Experts argue that most of the Chinese attacks are highly customised and specialised, with a high success rate, targeted at vital military installations, mostly vulnerable to industrial espionage (Bowlsbey, 2016; INFOSEC Institute, 2013).

Countries already drawn into cyber conspiracy and conflicts include the US, China, the UK, Israel, North Korea, Iran and Russia, all of whom are making serious coordi-

nated national efforts with respect to defensive and offensive capabilities. There are indications that the US National Security Agency (NSA) conceived the "US Cyber Command" as early as the year 2000, in order to build the US cyber warfare effort (Bamford, 2013). In his account, Bamford states that the US fears that "cyberweapons are as crucial to 21st century warfare as nuclear arms were in the 20th" (Bamford, 2013). Currently, it is estimated that the US Cyber Command force has over 14,000 personnel with over 13 formidable cyber attack formations (Bamford, 2013). Furthermore, the US is one of those countries that has continued to invest in cyber activities, as it is purported that the US sets aside about USD4.7 billion annually for developing cyber warriors, including expertise development via encouragement of doctoral degree studies in the various fields of cyberspace (Bamford, 2013; Miller, 2016). China, meanwhile, is building its cyber warfare paramilitary forces, understood to be especially targeting US expertise and specialisations in communications, electronic warfare and networking (Capaccio, 2012).

According a former UK Defence Secretary, "we will build in Britain a cyber strike capability so we can strike back in cyberspace against enemies who attack us, putting cyber alongside land, sea, air and space as a mainstream military activity" (UK Government, 2013). From the foregoing, the general concern is that the rise in cyber conspiracy and conflicts is capable of provoking a full-scale conventional war or cyber war, or a combination of the two. And there is already evidence that nation states or organised groups can launch digital assaults in the context of political and/or economic disputes. The potential for cyber conflict is no longer uncertain. Rather, the uncertainty is: who will be drawn into the cyber battlefields, and when and how? The cyber conflicts trend is increasing in frequency, scale, sophistication and severity of impact (Ranger, 2015), and the outcomes may be grave.

This widening of the elements of the digital divide – now including the ability to participate on the cyber warfare battlefield – is yet to be recognised by many developing nations, including many nations in Africa, who are encumbered by pressing domestic problems and socio-economic challenges. These local issues have, unavoidably, distracted attention from the emerging threats of the digital world (Epstein, Nisbet, & Gillespie, 2011; Mbanaso & Dandaura, 2015). With the scale of the events that are unfolding, it is fast becoming a necessity that every nation recognise the criticality of cyberspace as a domain of warfare. This requires African leaders to appreciate the urgent requirement to incorporate this domain into their traditional military operations of land, sea, air and space, making cyber conflict strategy an integral part of overall military strategy, with proportionate investment. Whether African leaders consider cyber warfare or not, the African continent will not be immune to cyber conspiracy and conflicts. And while cyber warfare could potentially become deeply embedded in contemporary military operations, there is at present no international convention on this matter.

The wars that rage in the cyberspace domain are likely to be very difficult to contain, due to several fluid factors. The factors that interplay and create the vulnerability landscape, which could be exploited by any invader against a target, are inherently unpredictable, increasing in severity as advancements are made in the technology arena (Lewis, 2011). A characteristic of cyber warfare is the minimal risk, and relatively low-cost weapons, required by an attacker to inflict significant impact on a target (Applegate, 2011). Another advantageous factor for attackers is the high level of anonymity and deniability afforded by conducting war-like campaigns in cyberspace (Applegate, 2011).

Conventionally, countries build "special forces", usually small formations of highly-skilled specialists who are seen as superior to all other forces. Combatting cyber warfare will need to fall into the category of matters engaged with by such forces, with lessons drawn from traditional special-force experiences. What are the commonalities and similarities between special forces and cyber forces? Several countries have dedicated vulnerability researchers combing cyberspace in an attempt to discover new weaknesses, as advances in technology characteristically breed new vulnerabilities (INFOSEC Institute, 2013; Shen & Nettis, 2016).

Another key point that should be understood in this context is the nature of the conspiracy and conflicts, which is, fundamentally, knowledge-based (Parks & Duggan, 2011; Shen & Nettis, 2016). It is not going to be business as usual, i.e., not a matter of buying tanks and weapons, as was the case in the traditional arms race. What is key, in this context, is the ability to carry out intellectual exploits, the capability to latch onto inherent vulnerabilities within cyberspace, through intensified and structured discovery, i.e., the ability of invaders to identify high-profile vulnerabilities, which even the vendors and manufacturers of technological devices and services find difficult to ascertain. The strength of every invader lies in its skills, expertise and competence in discovering high-profile, zero-day vulnerabilities. What this entails, as a knowledge-based event, is understanding that the threats are not static, but rapidly evolving, which makes reliance on other countries to supply cyber arms and cyber weapons a dangerous game (Capaccio, 2012; Parks & Duggan, 2011).

While some experts have argued that cyber war is unlikely on the scale speculated (Rid, 2011), there are pointers to the contrary. Presently, China and the US are in what can be qualified as conspiracy and cyber conflicts, with Chinese nationals already arrested for committing industrial espionage (Bowlsbey, 2016; INFOSEC Institute, 2013). Russia has been observed using massive cyber offensives to threaten its former allies, especially the Ukraine and Estonia (Applegate, 2011; BBC, 2007). North Korea is constantly using cyber offensives against South Korea (Kwark, 2015; Sang-hun, 2013; Reuters, 2016). To sum up, many of the conspiracies and conflicts seen among nations in the offline realm have shifted to cyberspace. The same sorts of conspirators, alignments and disagreements witnessed offline in past decades appear

to dominate, and even become magnified, in cyberspace.

The common denominator is that open, borderless cyberspace is a level playing ground for those who choose to invest in it. In the near future, nations' successes will be determined by their capacity and capability to maintain competitive advantage in the information space, i.e., cyber power capability. War based on cyber power capability will be difficult for any one side to win decisively except, perhaps, when combined with conventional warfare.

What may be most disturbing is the inconspicuous nature of nation states' capability, as there is no formal way to assess the true cyber offensive capability of a nation. Unlike the nuclear arms race that can possibly be assessed and constrained, nation states' particular cyber warfare capabilities can lie undetected. Moreover, the absence of international rules of engagement means that any full-scale cyber warfare has no recourse to any international law, even when it can have debilitating effects. While hacking of networks and information systems is an illegal activity, there is no international law addressing the use of cyber power against a state (Applegate, 2011).

Another perspective is that, as alluded to above, the cost of acquiring cyber weapons is relatively cheap, suggesting that poor states can invest little and harvest more, in terms of impact, in the cyber warfare arena. And with the borderless Internet characteristic of anonymity and deniability, nations in conflict can easily draw support from allies, since attribution is difficult.

Accordingly, based on this brief introductory overview, it is my view that studies in cyber security and cyber conflict must henceforth become a significant component of digital transformation research on the African continent.

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BOOK REVIEWS

Drawing Lessons from Case Studies of African Innovation: Review of *Innovation Africa* (Adesida, Karuri-Sebina & Resende-Santos, 2016)

Reviewer: Nagy K. Hanna
Visiting Associate Professor, LINK Centre, University of the Witwatersrand, Johannesburg; and former Senior Advisor on innovation and digital transformation, World Bank, Washington, DC

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Olugbenga Adesida, Geci Karuri-Sebina and Joao Resende-Santos (Editors), Innovation Africa: Emerging Hubs of Excellence. *Bingley, UK: Emerald, 2016, 352 pages, £29.95 (hardcover), ISBN Print: 9781785603112.*

This book covers eight case studies of innovation in various parts of Africa. These diverse cases cover innovation in several key sectors, across services, manufacturing, and agriculture, and spanning the private and public sectors. The cases include innovation hubs in Southern Africa, electronic government in Cabo Verde, mobile technology innovation in Kenya, Nollywood (the movie industry) in Nigeria, processing of agricultural products in Egypt, the sugar cane and tea subsectors in Kenya, the steel sector in Algeria and a large industrial cluster in Ghana.

Each case study is self-contained, with its conceptualisation of the national innovation system (NIS), its experience, and its lessons. The editors and authors ask how all these cases can scale up innovation for Africa.

This review does not attempt to cover all the cases, but rather uses selected cases to generalise lessons and insights about innovation in Africa, and to contrast these with the aims, frameworks, and recommendations of the authors.

The book opens with ambitious aims and aspirations. A new Africa is emerging. Africa needs transformative development. It needs to own its own narrative of the

future. A starting point is to promote an Africa-wide dialogue on innovation and structural transformation. In the opening chapter, the editors state their aim to make innovation a key element of the African development agenda and to promote evidence-based policy-making on innovation. They do not confine innovation to the "high end" (à la Silicon Valley), but extend it to the "low end", to cover inclusive and social innovation, capitalise on locally available and sustainable inputs, and solve everyday problems such as the need for clean water, efficient stoves, etc. They call for a policy focus by all stakeholders at country level, plus a regional pan-African focus, on building national ecosystems for innovation. The authors acknowledge that the book is a first-cut enquiry, a voyage of exploration, towards a systematic approach to support innovation-driven development for Africa.

The case of innovation hubs in Southern Africa is actually multiple cases of diverse hubs in several countries, ranging from traditional science parks, to activity-based innovation centres, to co-creation hubs. These hubs aim to provide an intermediary to link research to industry and other stakeholders.

Science parks require massive investments in infrastructure. Activity-based innovation centres are less capital- and infrastructure-intensive and more focused on directed, value-added activities. Co-creation hubs, a third generation of innovation centres, rely on building the soft enablers and practices of innovation: networking and collaboration among a broad range of stakeholders, open innovation, crowdsourcing, user- and community-driven innovation, and building on what already exists locally.

This particular case of innovation hubs is the most extensive in its coverage and lessons. The hubs' success often depends on having a committed research-based university as a base. Quality of physical and virtual infrastructures remains important, but the risk of over-reliance on a "build and they will come" dynamic is prominent in Africa. Critical success factors include having entrepreneurial communities, educational systems that encourage entrepreneurship, R&D that is aligned with local needs, supportive policies, and entrepreneur support networks.

Activity-based and co-creation models are organised around demand-driven design of activities, so knowledge generated is relevant to, and built around, local needs. These models depend on collaboration, trust, and communication. Critical success factors at contextual and strategic levels include promoting entrepreneurship at the national level, providing policy and strategy support to the hub, building governance and advisory structures involving key stakeholders, pursing partnerships, taking a long-term view of sustainability, providing stable leadership, communicating and seeking feedback from tenants, and piloting and phasing. The authors draw many operational lessons of particular value for African policymakers, financiers, and hub managers.

This rich case, and others that follow, suggest that innovation hubs are key intermediaries to synergise otherwise fragmented national innovation systems. When appropriately designed and led, they can facilitate collaboration at the local and regional levels, and attract talent and foreign and local investors with innovation focus.

A very different and interesting case is the electronic government of Cabo Verde. While many technological and business-model innovations are driven by the private sector, and for the benefit of firms and their clients, innovation can (and should) also happen in the public sector, for the benefit of society at large. This case shows how electronic government has revolutionised public financial management and provided the backbone for an electronic governance infrastructure for Cabo Verde. Again the NIS framework is used to conceptualise the interactions between the university (knowledge infrastructure), public institutions (policy, governance, politics), and private sector (production). The study points to the critical role of institutional innovation (creation of an autonomous professional national ICT agency), and of mobilising the substantial knowledge of the diaspora. The case suggests the potential use of the public sector to promote innovation, as a major consumer of innovation and a demonstrator of the power of digital transformation. But the case also illustrates the limits of this innovation in respect of spillover to the private sector, mainly due to the lack of collaboration among players in the NIS, and absence of a national innovation and ICT policy.

A third case that illuminates the workings of the innovation ecosystem (NIS) in Africa is the famed mobile technology of Kenya. It is a product of the local software developer community, telecom reforms and competition, the widespread adoption of mobile phones, and other enabling policies. It is also a product of business entrepreneurship, with mobile operator Safaricom creating and using the M-Pesa mobile money application as a platform for other companies to build value-added services, and closely interacting with its clients, pursuing innovative marketing, and continuously innovating its services. The case suggests several critical success factors that are of special relevance to innovation systems in the services sector: nurturing the developer (app) community for mobile, building public-private partnership with the ICT sector regulator, promoting local content development via a special fund, holding innovation (app) competitions, engaging the academic community, attracting R&D funding from multinationals for universities and pursuing universal connectivity. The absence of risk capital remains a key constraint to further scaling-up and sustainability of this innovation ecosystem.

The book shows that innovation is taking place in Africa. The above cases and the rest that are elaborated in the book bring the NIS framework alive. They show how this framework works in practice in diverse sectors, countries, and contexts. Yet, most of the cases are at early stages of developing a sustainable and scalable NIS.

They have yet to overcome significant constraints and be formally evaluated for their developmental impact.

The editors draw several lessons and recommendations. Most cases suggest important roles for government in setting enabling policies, rule of law, infrastructure, human resources, finance mechanisms for R&D, public procurement, and promotion of interactions among players in the NIS. And, at times, the public sector can lead innovation, as in the digital government of Cabo Verde.

The book's contributions make the case for an activist and smart government in building the NIS. In addition, the contributions generate a call for innovation policy to recognise the duality of Africa's NIS, to promote global competitiveness, and to address basic needs and solve everyday problems like money transfer, and clean energy and water. Third, the authors posit the need for a shared vision to mobilise all actors for a common future, and for actualisation of this vision through strategy, policy frameworks, and action plans. The authors suggest the need for more of a top-down direction, via public leadership, to overcome constraints and secure policy consistency over time. They argue, for instance, for import substitution strategies to stimulate indigenous innovation, as in the Cabo Verde and Algerian cases, and as has occurred in more advanced countries. Finally, they recommend the development of supporting institutions, with the means to carry out their mandates: to lead, catalyse, coordinate, incubate.

The book is not without its shortcomings. Its second chapter's heading is "Towards a unified theory of pan-African innovation systems and integrated development", an ambitious and unnecessary hill to climb. It posits "an alternative to all existing development approaches" to address the challenges of Africa, escape the raw material resource trap, promote green industrialisation, harness indigenous knowledge, and respond to local context and needs. It calls for rethinking both innovation and development theories.

While agreeing on the need for a context-sensitive framework, the reviewer finds this call for substantial reinvention of the NIS framework for Africa unconvincing. The authors of the cases cited above from the book have used the same NIS framework, or a slightly adapted version of it, and applied it to the context at hand. Many other countries also started with similar constraints as those faced by African countries, and learned to innovate by addressing the key components of their NIS and the interactions among them.

The challenge for Africa is to deepen and accelerate such learning, with increasing sensitivities to local realities and local stakeholders. There is more value to gain from working with this relatively universal framework and focusing on the most significant interactions within the system, aligning it with national development

priorities, piloting new institutional models for collaboration, measuring the impact of alternatives, and asking hard questions about the roles of government, universities, finance, communities, and other stakeholders.

Also, the editors tend to put too much faith in government as activist and leader of the NIS, and insufficient emphasis on the market, including small and innovative enterprises. This may be partly justified as a reaction to the neoclassical economic thinking (prevalent among the World Bank and other aid agencies), which emphasised government failures and neglected the need to nurture innovation in the context of a relatively weak private sector, and fragmented NIS.

Recent research supports a more proactive and diversified role for government, even among the most advanced countries like the US (Mazzucato, 2013; Stiglitz & Greenwold, 2014). But the book's case studies also point to severe limitations among government institutions, the risks of crowding out the private sector and the need for governments to learn before taking big leaps with major risks. In this context, the recommendation of relying on an import substitution strategy for Africa to secure demand for innovation could be risky and wasteful. It may be prudent to limit the government role here to creating the enabling environment, fostering entrepreneurial education, facilitating the functioning of the NIS and focusing government interventions on a few priority needs and local challenges, where market failures are prevalent and mission-oriented innovation can support inclusive and sustainable development.

One final limitation is the notion of high-end vs. low-end innovation, with high-end innovation associated with digital technologies à la Silicon Valley, and the low end associated with basic needs like clean water and other everyday needs. General purpose technologies (GPTs), such as the Internet and mobile, span both ends of innovation, and can be conducive to inclusive and social innovation, as well as innovation for competitiveness in industry and services. Perhaps a better differentiation is between incremental and breakthrough (R&D-intensive) innovations, with the former often more relevant for technology adopters in developing countries.

Future research on innovation in Africa can also benefit from an additional and complementary perspective: the role of digital technology (as a GPT) in inducing a technological revolution that impacts most sectors of the economy and demands profound social and institutional changes (Perez, 2010). This could be achieved by adjusting the social and institutional environment to take advantage of the ongoing digital technology revolution and its associated techno-economic paradigm involves disruptive innovation, the destruction of legacy systems and processes, and the invention of new practices and business models (Hanna, 2016).

The digital revolution is also transforming the very process of innovation, the

formation of innovation clusters and the workings of the NIS, by providing new tools for research, interaction, and collaboration, such as digital networking, open innovation, co-creation, crowdsourcing, simulation, big data, analytics, artificial intelligence, and the Internet of Things.

This is a pioneering book that should fill a significant gap in the literature on innovation in Africa and other developing and low-income countries. It sheds light, and lays out an agenda for research, on a poorly-understood and under-researched but increasingly important topic central to transformation of Africa's economies. It should be of interest to scholars, policymakers, development professionals, business leaders, and international financing institutions.

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Reviews of *Mastering Digital Transformation* (Hanna, 2016) and *Digital Kenya* (Ndemo & Weiss, 2016)

Reviewers:
Lucienne Abrahams
Director, LINK Centre, University of the Witwatersrand, Johannesburg; and AJIC Corresponding Editor

Kevin Goga
Court Assistant, Office of the Deputy Chief Justice and Vice President, Supreme Court of Kenya, Nairobi; and Postgraduate Student, LINK Centre, University of the Witwatersrand, Johannesburg

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Nagy K. Hanna, Mastering Digital Transformation: Towards a Smarter Society, Economy, City and Nation. *Bingley, UK: Emerald, 2016, 300 pages,* £29.95 (paperback), *ISBN Print: 9781785604652.*

Bitange Ndemo and Tim Weiss (Editors), Digital Kenya: An Entrepreneurial Revolution in the Making. *London: Palgrave Macmillan, 2016, 509 pages, free (eBook), ISBN: 978-1-137-57878-5.*

1. Opening comment

It is important that these two books were published in the same year, 2016, because together they reflect a more diverse set of perspectives than either one on its own, while demonstrating the common denominator of radical change relative to each particular country's locality, context or development trajectory. The books illustrate that even where countries are not be at similar levels of economic development, they all experience the digital revolution, resulting in both common and distinguishing features.

2. A perspective on Hanna's *Mastering Digital Transformation*: Learning and doing

Written in three parts, Hanna's major work on digital transformation attempts to map the new digital world, where people, organisations and markets, and the animate and inanimate instances that depend on them, are engaged in radical change of the geography, the landscape, indeed every facet of human activity. Part One on "The Big Picture", Part Two on "Pursuing Transformation Possibilities", and Part Three on "Mastering the Implementation of Digital Transformation", each deal with different modes of engagement with the transition from an analogue to a digital world – thinking, designing and achieving.

One of the reviewers spoke with the author and asked him: why the word "mastering" in the title of the book? Did this choice have anything to do with use of the word in the context of strategy, as related to Sun Tzu's implicit use of the idea of "mastery", with respect to self-mastery as a key leadership quality, for gaining insight in and navigating a changing environment? The author's response (December 2016):

> Digital transformation is a process that takes time and effort for integration of lessons, it requires learning to plan and planning to learn. You must design the plan and design the process in such a way as to learn and process/integrate as you learn from the experience […] this is "mastering" the process. These views are in contrast to those of donor agencies, who usually truncate the [digital transformation] process into a project cycle of short-term interventions […]. One of the dangers with the notion of leapfrogging is that it creates the impression that if you take the latest technology, you don't need the learning, or infrastructure, or policies and institutions, you just need to acquire the latest tech. But this is not true – the foundations need to be there for using the latest tech.

So the author is not using Sun Tzu, but the text of the book comes remarkably close to Sun Tzu's strategic thinking: make the strategy most relevant to the context to increase the chance of success. Relating the many discussions in the book to the African continent's experience, we would also emphasise the word "mastering", because it is now time to master particular facets of digital transformation in the 55 countries on the continent, relative to each country's context, rather than simply embarking on the journey. The existing levels of failure of digital development projects must breed greater levels of success, which success occurs through learning from failure and the application of such learning to advancement towards success, a transition typical in many innovation contexts.

Summary of selected chapters

There are many chapters deserving of comment, but we have chosen two that offer interesting ideas for contemplation for African countries.

Chapter 2's treatment of the "emerging smart, data-driven economy"

Hanna lists for the reader a few of the key terms associated with digital transformation today, of which we chose a few emerging modalities to explore in this review: frictionless economy, on-demand sharing economy, co-creation economy, orchestration economy, smart cities. The author also includes better-known terms, such as innovation economy and learning economy, important because innovation and learning underpin the possibility of engaging in the other modalities.

Summarising Hanna (pp. 15-23), data drive the frictionless economy through ease of mobile money transfer, through crowdsourcing, through online trading connecting manufacturers to buyers, and through using biometric identification to access public and private services. He writes that these "easy" transactions bring billions of the world's poor closer to digital opportunity, though new challenges emerge (e.g., privacy, consumer lock-in). As the author explains, data drive the on-demand sharing economy (à la Uber and Airbnb), with endless opportunities for connecting supply and demand of almost any kind of shared service, through integrated applications, incorporating digital mapping together with personal communication and online or mobile booking and other application elements. Data drive the co-creation economy, where citizens and consumers can create and recommend the kinds of services they seek from government and private-sector service providers. Data drive the orchestration economy, where global networks of suppliers are emerging and creating specialised resource bases to tap into, managed as networks of loosely organised people and parts rather than as highly hierarchical organisations. Data drive smart cities, through available data and the analytical capabilities to use the data to make major decisions on infrastructure, water, health, and other concerns. Hanna's provision of this range of ways to view digital transformation moves the reader away from attempting to "define" the term, towards exploring such transformation in all its guises.

Chapter 6's treatment of "transforming key sectors"

It is apparent from a reading of this chapter that, in the 21st century, the information and communication technology (ICT) sector is only as valuable as its capacity to transform other economic and social sectors. Here lies the challenge. For e-health, Hanna writes, digital transformation will require (p. 117) "a planned, sequenced, integrated and continuous approach" rather than a silver bullet. For e-education, countries and individual schools will need to (p. 129) "build a critical mass of trained teachers" to teach ICT skills and use ICT in all subjects and in all forms of educational engagement. Hanna argues that to transform finance, mobile money innovations must become widespread, and that (p.136) "[d]igitally-enabled agricultural transformation can help meet the challenge of feeding over 9 billion people by 2050 […]". He convincingly argues that in agricultural extension services, mobile communications can advance each element in the agricultural supply chain, including primary production, aggregation and processing, distribution, and the retail and consumer segment (p. 136).

Part of the value of Chapter 6 is that it deals with "key sectors" (health, education, finance and agriculture) from a global perspective – sectors that are foundational to all economies and nations, without which they cannot reasonably pursue digital transformation in other sectors. These four are sectors where digital transformation can make a significant difference to just about every person on the planet.

Review comments

As a critical comment on the book, it is our view that an even more explicit case could be made for digital innovation for the billions of citizens who are unlikely to experience most of the digital innovation opportunities discussed in this book, in their lifetimes. While this latest digital divide is implied in many sections of the book, and addressed to some extent in Chapter 7 on "promoting inclusive information society", it could be more explicitly addressed as a key theme, exposing the challenges that particular countries and social groups will face to achieve any form of digital inclusion and related economic emancipation. Some, few, countries are ahead at the game of mastering digital transformation. Some countries have had early realisation of benefits from a few, popular applications. Most countries require an even more detailed guide on the "how" of digital transformation. There is much to explore in this book, and at the same time so much more that can be added to its key themes.

3. A perspective on Ndemo and Weiss's *Digital Kenya*: Emphasis on entrepreneurialism for digital transformation

Digital Kenya is available free to download at http://link.springer.com/book/10.1057/978-1-137-57878-5, courtesy of the Ford Foundation. Published in four parts, the editors Ndemo and Weiss and the chapter authors present "Part I: Looking Back and Looking Ahead"; "Part II: Uncovering Unique Market Opportunities"; "Part III: The Inner Life of Technology Entrepreneurship in Kenya"; and "Part IV: Managing the Fine Details of Doing Business in Kenya".

The authors of the 15 chapters and 14 "conversations" (as the editors have labelled them) in this volume provide rich material for contemplation. The book is strongly geared towards entrepreneurship and the content is suggestive of both strengths and weaknesses in the entrepreneurial landscape. As reviewers, we are not entirely convinced that many of the ideas introduced by start-ups are at present being adopted by Kenyans in similar proportion to the mobile money innovation M-Pesa. Ushahidi, for instance, while a Kenyan innovation, is now mostly used in other parts of the world.

Summary of selected segments

Conversation #1: "The Past, Present, and Future of 'Digital Nyika': How to Fix an Aircraft in Flight"

The reflections of Gitonga, in the first conversation, on the "Digital Nyika" ("*nyika*" meaning "grasslands" in Swahili), highlight the risks for future digital innovation

in Kenya. He notes a tendency to import foreign technological approaches rather than creating home-grown innovations, though this is changing. From the reviewers' perspective, a good example of this shift to local innovation is the introduction of taxi-hailing apps. When Uber first came to the Kenyan market, there was some resistance, but with time, it grew to be accepted. More recently, Kenya has competing apps, such as Safaricom's Little Cab, taking on Uber.

Gitonga argues that digital innovators and entrepreneurs should emphasise pressing local problems. Here, they will get larger numbers of users and, if the initiative is really of value, the sustainability is almost a given provided there is focus on continuous improvement.

Chapter 3: "The KINGS of Africa's Digital Economy"
This chapter by Osiakwan paints a brief picture of the driving factors for digital innovation in five countries, namely Kenya, the Ivory Coast, Nigeria, Ghana and South Africa. While the chapter discusses the notion of "Africa tech rising", and the first wave of tech innovation, it does so in a limited way, the emphasis rather biased towards infrastructure, with only a cursory glance at digital innovation and enabling or constraining policy environments in the five countries.

Nevertheless, Osiakwan's notion of "first mover countries" on the African continent – countries to watch, countries to emulate – is useful for two reasons: (i) it suggests to the reader that there are particular countries to learn from in Africa, though the leading countries may change with time; and (ii) it gives African countries a sense of what may be possible in their own contexts, if they can follow the examples of fellow African countries with similar development trajectories and socio-economic challenges.

Chapter 11: "Inside a Policymaker's Mind: An Entrepreneurial Approach to Policy Development and Implementation"
Ndemo's reflections, in this chapter, on approaches to policy development and implementation are valuable. Having served as the Permanent Secretary to Kenya's Ministry of ICT, he is able to take the reader on a tour of the inner sanctum of government, where policy is conceived.

Review comments
As reviewers, we are sceptical that many of the ICT-based services introduced by Kenyan start-ups are being adopted by Kenyans to the same extent as the mobile money innovation M-Pesa and other mobile financial services. More evidence of adoption rates for the many digital innovations – for example the number of players of the Moraba digital game – will be a valuable focus for future research.

Understanding adoption of local innovation will be important because it will enable

us to understand the most crucial parts of the Kenyan ecosystem for continued, long-term digital innovation, noting that high levels of adoption can breed continuous demand for innovation, while low levels of adoption can lead to stagnation in the digital innovation space. Also vital to the future growth of innovation is that researchers study digital innovation – in Kenya and other African countries – beyond the ICT infrastructure perspective, making available research-based knowledge on the services, innovations and techno-cultural artefacts that use ICT infrastructure for digital transformation of African economy and society.

A subject that could have been addressed more explicitly in the book is the need to inculcate a culture of matching relevant skill sets, such that innovators and entrepreneurs complement each other and in the process build solutions and future business. Such dynamics are necessary to build sustainability of solutions and stabilised management of small, local, tech-driven companies. The future of "digital Kenya", in our view, lies to a great extent in encouraging Kenyans to harness home-grown solutions to local problems. Such issues are indeed highlighted in the chapters and conversations of this volume, but would have merited a dedicated chapter.

In light of the insights from this volume, how do we see Kenya's digital future? The next generation of policymakers will be young people who are prickly in their conduct towards bureaucracy. It is therefore necessary to ensure that the education and insights these future policymakers acquire, both at universities and in the various technology and tech policy fora they engage with, give them the capacity to craft policies that will enable the African digital future. That will be central to making digital Kenya, and digital Africa, real.

4. Conclusions

Those readers seeking to understand Africa's economic, social and political transformations can benefit from reading these two volumes, *Mastering Digital Transformation* and *Digital Kenya*. The broad conceptualisation of digital transformation that emerges from these books forces the discussion beyond technologies, beyond ICT infrastructure, and beyond ICT policy, to the many drivers of digital development in the next decade and beyond, such as the requirement for innovation skills and capabilities, and the demand for innovative services and transformational impact.

While ICT infrastructure remains a valid descriptor, we argue that, based on the insights from these two volumes, the age of ICT policy is past and the age of digital transformation and digital innovation policy is with us. Why do we say "digital transformation and digital innovation policy"? Our view is that "ICT policy" as a descriptor does not capture the necessary disruptive nature, nor the necessary creativity or innovation capability, which are more explicitly embraced by a notion of policymaking for digital transformation and digital innovation.

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