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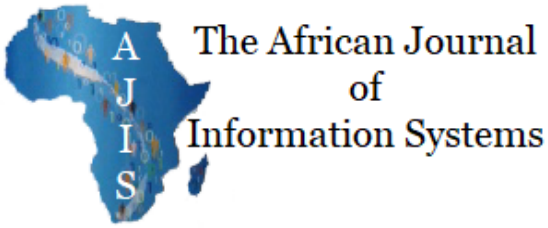

Development of Research Administration and Management System for Higher Education Institutions in Developing Countries: Case Study of Durban University of Technology

Research Paper

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ABSTRACT

Research information management has become an essential activity for higher education institutions (HEIs) worldwide as a mechanism to aggregate, curate, utilize and improve the transparency of information about research. It has led to the evolution of proprietary software systems for administering and managing research information in HEIs. However, the literature reveals that most proprietary software systems are usually inflexible, costly to maintain and do not adequately satisfy the dynamic requirements of HEIs in developing countries. Consequently, the demand for current information systems is to incorporate a high degree of formalism into software development processes to produce correct, flexible, usable and cost-effective systems. This paper reports on the development of a web-based research administration and management system (RAMS) that addresses pertinent issues associated with research information management in the context of HEIs in developing countries. The Zermelo-Fraenkel specification language has been utilized to formally specify the requirements of RAMS in close collaboration with the intended users who evaluated its usability. The overall results of the usability evaluation show that RAMS is effective, useful, easy to use, learnable and satisfactory.

Keywords

Formal method, Management system, Research administration, Research information, Requirements specification.

INTRODUCTION

Research has become one of the main activities of higher education institutions (HEIs) to put them on the world map of creativity. It enhances the reputation and advances competitiveness of HEIs in the global market (Carter & Langley, 2009). Increasingly important is research information that emanates from the conducted research, which is one of the major sources of funding for HEIs. Research information refers to metadata about research activities such as researchers' profiles, projects, collaborations, supervision, publications, published data sets, patents, funding, awards, reports and infrastructures. High quality research works from HEIs have attracted government funding in many countries because research is widely recognized as the foremost driver of creative innovation that impacts on sustained economic growth of a country (Nicolaides, 2014; Bayarçelik & Taşel, 2012; Carter & Langley, 2009). Funding opportunities come with stringent requirements that HEIs must fulfil at all costs. For instance, some governments and funding agencies have mandated that HEIs make research information public for individuals and private organizations to draw on (Amorim et al., 2015).

The lack of resources to develop appropriate research information management systems has been identified as one of the major problems in HEIs (Njuguna & Itegi, 2013). Research information management systems are archetypes of information systems that use different approaches and mechanisms to collect, curate, manage and provide access to content and research identity information (Stvilia et al. 2018a). The South African government, for instance, has attempted to address the problems of research information management through the use of a proprietary research information management system (RIMS) in the public HEIs (RIMS, 2011). Nevertheless, some HEIs still face problems regarding the effective use of the system, as most proprietary systems do not adequately satisfy the desired requirements of users (Jeffery, 2012). In addition, proprietary systems are costly to acquire and maintain (Pankaja and Mukund, 2013). Many HEIs may not be able to immediately upgrade their information systems to implement the desired features resulting from strategic directions because proprietary systems usually do not allow access to their source code. In such cases, HEIs are forced to make special requests to system proprietors to implement newly required features, which may be costly. Moreover, absolute reliance on proprietary systems can result in a situation that proprietary vendors lock-in clients by creating switching costs. Software vendors can lock-in clients by making their systems incompatible with other software, using proprietary standards that lack interoperability with other systems and licensing the software under exclusive conditions (Zhu & Zhou, 2012). A study by Green et al. (2012) reveals disparity in terms of functionalities from one proprietary system to another.

Most proprietary systems are developed following ad hoc approaches and without fully understanding the requirements specification of individual HEIs. Requirements specification is an important business in software development process because it brings system developers and real users to a common understanding about the essential needs for a system. The lack of consensus among different stakeholders often results in systems that have technical barriers, which make users shun from using them (Jeffery, 2012). Such systems do not adapt very well to devices with small screens like mobile phones and often lack appealing interfaces. The original purpose of this study is to develop a usable web-based research information management system in collaboration with real users and to test its usability in the context of HEIs in developing countries. Although a significant body of literature exists on approaches and mechanisms for research information management (Stvilia et al., 2018a), how researchers use research information management systems for sharing identity information (Stvilia et al., 2018a), what motivate researchers to engage with research information management systems (Stvilia et al., 2018b) and challenges of managing research information (Biesenbender, 2018). However, there is

still a dearth of literature on what constitutes an ideal research information management system. In addition, comparative analysis and usability evaluation of existing research information management systems have not been adequately dealt with from the perspectives of the real users. In particular, usability is an important property of information systems because any system developed for people should possess high usability (Joshi et al., 2019). Moreover, usability evaluation is an important principle of user centric design (Teka et al., 2017). Systems with poor usability can result in high error rates, huge support costs and long training times that will eventually increase user dissatisfaction (Joshi et al., 2019). This article contributes uniquely to filling these gaps by examining the following important research questions:

a) What are the challenges of research information management in the context of HEIs in developing countries?
b) What are the characteristics of an ideal research information management system in the context of HEIs in developing countries?
c) What are the user perceptions on the usability of a research information management system developed in the context of HEIs in developing countries?

LITERATURE REVIEW

This section provides a review of the relevant literature on the benefits and challenges of research information management. In addition, it discusses the characteristics of an ideal research information management system in the context of HEIs in developing countries. Moreover, it provides a comparative analysis of some existing non-proprietary research information management systems.

Research Information Management

Research information management is an extremely important activity for HEIs in developing countries. The potential benefits expected from research, technology and developmental goals set by most HEIs would simply not be realized without effective management of research information (Langley, 2012). HEIs are the major source of high quality and validated research information and are recognized by governments worldwide as crucial national assets for their positive contributions to the socioeconomic development of a nation (Langley, 2012, Ghvedashvili et al., 2011). Consequently, many governments, national and international institutions have considered research information management in HEIs as crucial. A well conducted research information management practice is a key to the success of any research university in modern times (Ghvedashvili et al., 2011).

Curdt & Hoffmeister (2015) stated that many national and international institutions such as the National Science Foundation (NSF), Organization for Economic Co-operation and Development (OECD) and United Kingdom (UK) Research Council (UKRC) have emphasized the importance of research information management in recent years. This view is evident in the promotion and establishment of research information management infrastructures and policies in various HEIs worldwide. Delasalle (2013) wrote about a success story of research information management practice at the University of Warwick where a policy compatible with the requirements of funders and satisfy the specific needs of the University was implemented to set the direction for best practices in research information management. Hodson & Jones (2013) mentioned policy and strategy as one of the seven rules for successful research information management in universities.

There are many inherent benefits realizable from a proper practice of research information management in HEIs. It showcases research outputs to a global audience and stakeholder groups such as academic staff, researchers, students, funders, professionals and external collaborators. Indeed, in these times where competition for a limited grant is highly tensed, HEIs stand to benefit from a multidisciplinary approach to research, which is an essential criterion that proposals are evaluated (Andersen, 2010). In addition, collaboration between institutions, groups and individuals could help to make research information management more efficient by reducing duplication and avoiding data loss (Kahn et al., 2014). Collaborative research ensures compliance with the expectations of most funding bodies of research data. For instance, Halbert (2013) reported that most funding agencies in the United States, such as the National Science Foundation (NSF), National Institutes of Health (NIH) and National Endowment for the Humanities (NEH), have mandated data management plans as a fundamental requisite for a research grant application.

Langley & Green (2009) stated that universities that are successful in securing research funding are required to fulfil a range of obligations of which research information management is mandatory. Research grants and contracts are heavily verified, rigorously monitored and often tied to negotiating milestones and deliverables. Bruce (2014) and Pink (2013) reported that the Engineering and Physical Sciences Research Council (EPSRC) of the UK stated that institutions that receive funding for research must have developed a roadmap outlining support for researchers in implementing responsible and sustainable reuse of their data. In addition, Bruce (2014) wrote that managing research data is a crucial contributor to fulfilling the basic requirements of research funders and it attracts new collaborators nationally and internationally. HEIs need to demonstrate research excellence by making their studies and data noticeable with the hope that they will drive new and exciting research efforts. It will ultimately help achieve research excellence that in turn will boost economic growth. It facilitates direct sharing and re-using of research data for future research endeavor and accelerates the generation of new knowledge. A good practice of research information management increases access to reliable information and improves the sharing of new ideas, thereby raising the prestige of HEIs, encouraging innovation and creating new growth opportunities.

Dora & Kumar (2015) asserted that opening research data sets for public consumption enhances the visibility of HEIs and their researchers. They avowed that long-term preservation of data provides for validation check and enhances credibility and transparency of research data used. In addition, they stated that a well managed research data practice can enhance the understanding of the existing research on data and can ensure the visibility of research outputs from publicly funded research. Moreover, they mentioned that a well managed research data practice can enhance data discovery, facilitate quality research and are economical to reuse, which saves time and resources for an institution. Van den Eynden et al. (2011) contended that a well organized, documented, preserved and accessible research data set with controlled accuracy and validity, always result in high quality data, efficient research findings based on solid evidence and it can save time and resources. In fact, a high quality research can be realized when researchers have unlimited access to an extensive range of relevant research data produced and made public by other researchers nationally and internationally.

Research information management activity brings great opportunities to improve the pace and effectiveness of a scholarly inquiry, provided the relevant data can be discovered, reused and recombined in creative ways (Lynch, 2014). A good research data management practice can allow reliable verification of results and pave way for innovative research based on the existing research information (Van den Eynden et al., 2011). Mossink et al. (2013) stated that a good research data management activity is essential for productive research and optimal use of new data infrastructures.

They explained that effective management of research information is crucial for generating economic, scientific progress and preserving this capital for future generations, thereby creating a long impact after the original research (Amorim et al., 2015). Research data management makes information accessible to other researchers, thereby facilitating validation and supporting innovative research (Brown et al., 2015). Consequently, HEIs are encouraged to embrace flexible and productive research information management practices to realize the aforesaid gains and other intrinsic benefits (Ghvedashvili et al., 2011).

Challenges of Research Information Management

It is important to comprehend the inherent challenges of research information management in order to define the characteristics of an ideal research information management system. Despite the many intrinsic benefits that could be realized from research information management, many HEIs in developing countries are facing numerous challenges. It is difficult for them to provide tools that allow the right people to create, publish, find and preserve the right research content based on the needs of an institution (Yanosky 2009). Challenges that are connected to this difficulty include ownership, preservation and interpretation, so HEIs need to support the long-term preservation of research data (Yanosky 2009). This could, of course, be achieved in several ways, but research information management cannot be disregarded as it is at the heart of long-term preservation of research data. Jahnke & Asher (2012) highlighted that digital technologies have brought new opportunities for researchers to create data sets that enable increasingly sophisticated analyzes. However, the haphazard management of data and data preservation strategies endanger the potential benefits that come with the advancement.

Many HEIs are facing a serious challenge of preserving and managing voluminous research data (Winn, 2013), especially in this era of big data, internet of things and fourth industrial revolution in general. The institutions are challenged by the huge growth in the volume of research information that they produce regularly and are required to manage (Williams & Hardy, 2011). Kahn et al. (2014) stated that the sheer volume and distributed nature of information emanating from research has amplified the challenge of collecting, storing and reusing research data. Sripada (2002) elucidated that long-term research data storage and associated data management practices are one of the most critical research computing needs that is not being met by many HEIs. The author further highlighted the requirements to provide the "right information, at the right time, to the right people, in the right context and in the right format" that addresses many of the information management challenges. Njuguna & Itegi (2013) asserted that financial constraints, especially HEIs in the developing countries of Africa, negatively impact research, including its mission, processes, dissemination, preservation and integrity of the participants. Most HEIs in the developing countries are facing the challenges of inappropriate infrastructures, lack of plans, policies, common data sharing standards and state of the art resources (Naidoo, 2007), which make them to carry out research information management haphazardly (Tsang, 2014). Nurminen (2014) and Laitinen et al. (2000) noted that most HEIs in Finland have succeeded in building their own research information management systems.

There is a lack of a coordinated approach to research information management in HEIs (Bruce, 2014). The study of Langley & Green (2009) has revealed that HEIs without a research strategy were not confident to have achieved their research goals. They will not be able to effectively use the information collected without the right tools and technologies. Cox et al. (2014) reported that the majority of HEIs do not have research data management infrastructures because of their lack of resources (Kabiawu et al., 2016), in particular financial resources (da Silva et al., 2014). In addition, the issue of research management approaches was alluded to by Langley & Green (2009) and they referred to it as a lack of

research strategy. The literature has revealed that in some HEIs, there are small systems in different departments for research information management, but these systems are mainly operating in silos and are not well integrated for administrative purpose. Information on the research output and content of research are held in numerous systems that are run by different organizational units using different formats and data models. This makes it practically impossible to combine, aggregate or integrate rich information (Scholze & Maier, 2012).

Managing research information in a silo brings in risks and other challenges as HEIs cannot consolidate and standardize their research management processes, preventing them to reduce costs of system maintenance. Quix & Jarke (2014) highlighted that standardization, harmonization and integration of research information are the frequently mentioned challenges, especially where computer-based systems have not been implemented. Different attempts have been made at the international and national levels to standardize the collection, processing and exchange of research information by harmonizing the underlying definitions, data formats and technical systems, but systematic insights into the dynamics of such complex processes are still lacking (Biesenbender 2018; Riechert, et al., 2016). Biesenbender (2018) provided an exploratory evidence of conceptual frame for analyzing and comparing direct and indirect research information standardization processes based on a case study of German and Italian science systems. The study result shows that policies regulating the institutional processing of research information might lead to standardization of research information in science (Biesenbender 2018). HEIs can reduce costs, time and effort needed for managing their research information by making a cross-institutional and departmental merger of different systems. The role of the libraries, researchers, senior leadership and information technology teams have been emphasized (Bryant et al., 2017) as well as the need for stakeholders to work together to achieve a coordinated approach to gathering and maintaining the integrity of research data in HEIs.

The persistent challenges of research information management in many HEIs in the developing countries of Africa are primarily caused by the "failure of governments to implement policies that recognize the fundamental impacts that research activities could have on governance" (Njuguna & Itegi 2014). The challenges can be appositely classified as technical, socio-cultural and ethical hegemony (Curdt & Hoffmeister, 2015). Moreover, insufficient communication between the involved researchers and research managers in the system design process is a major challenge that has resulted in a lack of acceptance of the system and a low motivation to provide data (Curdt & Hoffmeister, 2015). The primary functions of university research offices and the huge demand on staff managing research information have become more varied, growing to embrace a wide range of responsibilities (Green et al., 2010). This implies that usable research information management systems are essential in such environments for these individuals to effectively carry out their operations faithfully. Curdt & Hoffmeister (2015) suggested the following guidelines to solve the aforesaid problems. The integration of research information management system in the entire research process at an early stage. The continuous communication between researchers and data managers during the design process of a research information system. The establishment of user-friendly system interfaces that facilitate easy interaction with minimal demand from users. The continued provision of technical support and training for researchers on the effective use of the system.

Ideal System for Research Information Management

The numerous challenges of research information management in HEIs call for a proper understanding of what constitutes an ideal research information management system. In fact, an ideal research

information management system is a hypothetical system that can guide the improvement of a practical research information management system.

First, an ideal research information management system should be tailored to the common needs of HEIs. It should serve to comply with the global requirements of government and other stakeholders. Due to the rapidly changing requirements that may be unforeseen, it should afford a high degree of flexibility to accommodate the immediate and future changes in requirements of different stakeholders. It should be capable of taking new requirements into account without having any changes in its frame. Research data stored in the system should be reliable, verifiable, consistent and the system should support both administrative and management operations in order to be used for reporting purposes. The costs of system development and maintenance should be minimal to increase accessibility to research information.

Second, since the use of the internet technology in developing countries has impressively increased in recent times and has changed how knowledge is produced, managed and disseminated, an ideal research information management system should be web-based to increase access to research information (Avgerou et at., 2016; Nyirenda-Jere & Biru, 2015). Web-based systems generally come with many intrinsic benefits, including unlimited accessibility and cost effective deployment. They are cross-platform compatible, fairly standardized and easy to maintain. An ideal research information management system should allow for quick and easy data entry, be stimulating and pleasurable to use. It should provide value-added services for users rather than creating additional burden. The reporting should be organized such that users are relieved of the burden of having to supply the same data several times. The data collection mechanism of the system should be efficient, simple to use and input processes should ease the burden on individual users. All of these attractive characteristics can be achieved by adapting the system to the needs of HEIs in developing countries as far as research information management is concerned (Baguma et al., 2013).

Comparison of Research Information Management Systems

There is a dearth of literature on research information management systems in HEIs of developing countries. Most systems that appear in the academic literature are specifically tailored to the needs of HEIs in the developed countries as far as research information management is concerned. Green et al. (2012) provided a comparative analysis of some of these systems that are mainly proprietary. Their analysis was based on a survey they conducted in different HEIs, which revealed that there was a great disparity in terms of functionalities in the systems. Table 1 presents a comparative analysis of in-house research information management systems that have been implemented in some HEIs. This comparison follows the method of a document analysis that is inherently an indirect approach (Wiegers & Beatty, 2013). The rationale for committing to this approach lies in the fact that in-house systems are inaccessible because they are designed with a goal to address the needs of a specific organization. Consequently, the analysis of this study focuses essentially on the functionalities, development approaches and communicated values of the systems. It is paramount to highlight that some of these reviewed systems had incomprehensible descriptions regarding their functionalities.

Table 1. Comparison of research information management systems

System and Author	Functionality	Approach	Benefit
Tbilisi State	User profile – curriculum	Web-based, uses	Enables the visibility of

University Research Portal (TSURP) (Ghvedashvili *et al.,* 2011).	vitae (CV), publications, research projects.	MySQL database and built on the Joomla platform.	researchers and their research projects in Georgian HEIs. The system provided new opportunities for national and international collaboration in HEIs and scientific community (Ghvedashvili *et al.,* 2011).
Scientific Research Information System (SRIS) (Gaspar *et al.,* 2013).	Measurement planning, data collection, analyzes, projects, finances and publications, qualitative parameter evaluation, evidence and control and laboratory diary.	Built based on the Common European Research Information Format (CERIF), which is suitable for a wide range of research environments in Europe.	Provides technical point of view for managing research information (Gaspar *et al.,* 2013).
Scientific Research Management System (SRMS) (Zhang *et al,.* 2009).	User management, collecting, examining and querying scientific research information, and ranking of scientific research information.	Not clearly communicated.	Solves the problem of managing the plentiful research information on colleges in China (Zhang *et al.* 2009).
Czech Research, Development and Innovation Information System (CRDIIS) Chudlarský & Dvořák, 2012).	Research projects, institutional research plans, R&D result records, cleansed R&D results, research and development calls and funding schemes.	Developed based on the Current Research Information System (CRIS) model for managing research information in Europe.	Increases accessibility to research information and contributes to transparency in the research domain, which leads to an enhanced level of trust, more open competition, strengthens equality of opportunities and information access equality in Czech Republic (Chudlarský & Dvořák 2012).
Clinical research administration (CLARA) (Bian *et al.,* 2014).	A standard compliant user authentication and role-based access control. An integrated platform that supports collaboration and communications across regulatory and	Not clearly communicated, but it is web-based.	Solves technological and design deficiencies of previous systems such as scalability issues of back-end databases; data inconsistency and quality issues, slow system

	administrative bodies. A flexible reporting unit that supports a wide variety of data extraction requirements. A feature that handles auditing of various research publications. An extensible interface engine for connecting to other clinical and research systems and an extensible version and change control component. A study calendar-like budgeting tool and a set of tools and metrics for benchmarking clinical research administration workflows.		performance, bad user experience and lack of support for data extraction and reporting (Bian *et al.*, 2014).
Research Administration and Management System (RAMS) (our contribution).	Manages publications and generates a variety of formatted reports of which some are required for subsidy. It manages research projects, grants, awards, collaborations amongst researchers and conference funding application. It generates a list of references in the Harvard style. It builds a profile of researchers and generates curriculum vitae in the pdf format. The system allows for communication between students and supervisors as well as between researchers. It includes a module for monitoring student progress and provides a complete overview of research for research managers for decision making.	Web-based, uses MySQL database. Adapts to different devices and accessible on mobile devices.	Significantly enhances the visibility of researchers and their research projects as it is web-based and people can access and view the profiles of researchers. The visibility opens doors to new funding opportunities. The system potentially increases accessibility to research information and provides new opportunities for national and international collaborations in HEIs and the scientific community. It is a cost-effective solution to resource constrained HEIs in developing countries. It increases access to research information for innovations.

METHODOLOGY

This study falls into the information systems (IS) discipline because it addresses a practical problem of research information management in HEIs. It appears lucidly that the prime goal of IS discipline is to address the problems of people, organizations and technologies (Hevner et al., 2004). This discipline continues to develop rapidly and change constantly over time as the world continues to face more challenging problems on a daily basis. Consequently, several paradigms have emerged with the purpose of tackling the diverse aspects of research problems within the IS discipline. The study of Niehaves & Stahl (2006) mentioned six examples of paradigms that exist in the IS discipline to be positivism, interpretivist, behavioral science research, design science research (DSR), critical research paradigm and non-critical research paradigm. In particular, Peffers et al. (2007) proposed the design science research methodology (DSRM) as a unifying methodology for design science principles proposed by other researchers. DSRM incorporates certain principles, practices and procedures to carry out design science research in the IS discipline and it facilitates multiple entry points in the development process of an artifact. Due to its consensus building approach, DSRM has been widely accepted in the IS discipline and other related publication channels (Hevner & Chatterjee, 2010). This research has applied the DSRM to study how research information is managed in HEIs, besides gaining a deeper insight into problems that are faced by HEIs in South Africa using the experience of Durban University of Technology (DUT) as a case study.

The process leading to the development of RAMS started with the determination of system requirements, which is a central activity in software development. Failing to scrupulously capture system requirements is a prime reason for the failure of software projects (Schneider et al., 2016). The requirements of RAMS were collected through several context interviews conducted by the researchers and staff in the research and postgraduate support office (RPSO) at DUT. Relevant documents related to research information management obtained from the RPSO at DUT were punctiliously examined. Moreover, a comprehensive review of literature around the theme of research information management was carried out to provide rich and useful information. Context-free interviews and examination of relevant documents were primarily intended to understand the important activities of research information management at DUT. The case study has provided a deeper insight into the understanding of the characteristics of an ideal research information management system. In addition, the literature review has helped us to gain a deeper understanding of the problem at hand and draw lessons from other institutions that faced similar problem on how they have addressed the problem.

SYSTEM SPECIFICATION

The requirements specification of a system is an important business in software development because it helps to communicate the actual problem to be solved between the developers and users in an unambiguous manner. It has a direct impact on the quality, maintenance, financial costs and success of system development (Yusufu & Yusufu 2008). Many studies have shown that a system whose requirements are not properly specified often become ineffective and fail to adequately satisfy the users. Requirements specification ensures that all uncertainties on requirements are cleared and a consensus is reached between users and developers before the development commences. Johansson & Rolandsson (2012) affirmed that the requirements specification serves as a channel of communication, conveying the characteristics of a system between developers and users. Escalona & Koch (2004) stated that requirements specified in software development are crucial as they assure the quality of the resulting software. Methods of specifying system requirements can be classified into informal and formal approaches. Informal methods include the use of scenarios, natural languages and use case modeling

(Escalona & Koch, 2004). Formal methods include the use of formal languages such as the Zermelo-Fraenkel (Z) for formalizing mathematics, Vienna development method (VDM) for formalizing a communication protocol, Temporal logic of actions (TLA) for formalizing distributed algorithms, Object constraint language (OCL) for precisely defining the well-formedness rules for the unified modeling language and Petri Net for modeling concurrent systems among several others.

The use of formal methods for requirements specification provides advantages over informal methods. The specifications of requirements produced using formal methods are more precise than those produced using informal methods (Escalona & Koch, 2004). The precision forces ambiguities to be questioned and removed faithfully (Hall, 2007). Moreover, a formal specification is an abstraction that allows a human reader to understand the big picture of the system being modelled (Hall, 2007). It forces the analysis of requirements at an early stage and guarantees that any inherent errors are corrected faithfully at this stage instead of modifying a delivered system, which could be costly (Sommerville, 2009). Thus, the attention to system correctness at early stages pays off in reduced rework costs (Hall & Chapman, 2002). In addition, the use of formal methods can tremendously help to decisively impact the specifics and characteristics of a system at the beginning of a project development because at this stage most users are usually not exact about the system requirements (Sharma, 2016; Batra, 2013). Hence, formal methods ensure the implementation of a software product that satisfies the specified requirements (Batra, 2013).

RAMS houses information on researchers, publications, conference funding applications, research projects, patents, awards, grants and collaborators. Information about researchers include personal details, qualifications, employment records, professional registrations and research areas. The system uses this information to generate a profile that provides information about the publications of a researcher. In addition, RAMS provides a functionality for a researcher to generate a complete curriculum vitae (CV) in pdf format. The structure of the CV is consistent for every researcher. The information about publication includes books, book chapters, conferences, creative artwork and journals. The metadata of research outputs is entered as a single record in RAMS, regardless of the number of contributors and whether they belong to different departments or not. However, contributors can view the articles in their profiles and articles do appear in their CVs. This is made possible because of the data linkage within the system that makes it to associate research outputs to contributors and their departments. RAMS provides the researchers with a functionality to apply to the RPSO for conference funding. The responsible personnel can assess the application and based on the assessment, provides feedback to the applicant. Popup notifications about funding applications are provided to researchers and a personnel who assesses the applications.

Based on the feedback received about an application, the researcher can rework the application and resubmit it for reassessment. Once the application is approved, the assessor is supposed to forward it within the system to a personnel in the finance department for further processing. This process includes notifying the applicant about the receipt of the approved application and the actual transfer of funds to the account of the applicant. However, it should be noted that the functionality for forwarding an application to the finance department is still under development. Moreover, RAMS enables the researchers to record information about their projects, patents, awards, research grants and collaborators. It can generate assorted types of reports, including internal and progress reports. For instance, in South Africa, government funded HEIs can utilize RAMS to generate formatted reports of outputs that are required by the Department of Higher Education and Technology (DHET) for subsidy purpose. Moreover, the system can assist the research managers to easily and quickly gain a comprehensive

overview of research in their respective HEIs. Based on the overview of research, the research manager can make decisions on how to stay ahead of other HEIs in terms of research.

The design of RAMS was accomplished using the basic steps of the DSRM of which specification, implementation and evaluation are essential. The DSRM does not naturally enforce rules on how design should be done and what tools to apply, which makes the system requirements specification, after requirements elicitation to be modeled using the Z specification language. The specification language is one of the most revered languages of formal methods (Latif et al., 2007) that has been widely used by many researchers (Bakri et al., 2013). It is easier to present a formal specification, as small and easy to read the portions known as schemas in the Z language. Schemas are easy to distinguish from the associated text through graphical representation. Z formal specifications would be difficult and tedious to read without the use of schemas, especially where large mathematical formulae are involved. The Z language has a wide range of tools for producing the formal specifications and its variant tools are provided free of charge on the Internet. The language is robust in terms of the models produced as errors in requirements are significantly reduced. As is common with many formal methods, more time is invested at an early stage to get rid of the incompleteness and inconsistencies in the system requirements. Some of the Z specifications for RAMS are presented in Figures 1, 2 and 3. In particular, Figure 1 shows a schematic for logging into the system. The system requires each user to provide a username and password to authorize access for the user. If the supplied username and password match those in the system, the system responds success and the user is authenticated to use the system. However, if the supplied username and password do not match those in the system, the system responds with login failed notification.

Login

Δ *Members*
username?: *TEXT*
password?: *PASSWORD*
Response!: *RESPONSE*

If *username* $\cap$ *password* $\in$ *Member*
Response! = *LOGIN_SUCCESSFUL*
else *Response*! = *LOGIN_FAILED*

Figure 1. Z Schema for login operation

Figure 2 shows a schematic for adding a journal. It ensures that the new record does not already exist in the system. If the record already exists in the system, it is not added and an error message will be displayed. If the new record does not already exist in the system, it will be added and a message of successful operation will be displayed.

AddNewJournal

Δ *Journals*
author?, *exauthor*? : *AUTHOR*
internal?, *vol*?, *jissue*? : $\mathbb{N}_1$
external? : $\mathbb{N}$
yr?, *ryear*? : *YEAR*
t?, *journal*? : *TEXT*
jissn? : *ISSN*
pagerange? : *RANGE*
jdoi? : *DOI*
jurl? : *URL*
success!, *response*! : *RESPONSE*
doc? : *FILEPATH*

$\exists x : Journal \bullet x.title = t? \land x.year = yr?$
$\Rightarrow response! = RECORD\_ALREADY\_EXISTS$
$Journal' = Journal \cup \{ x : JOURNAL \mid x.authors = author? \land x.exauthors = exauthor? \land$
$x.internal\_authors = internal? \land x.external\_authors = external? \land$
$x.year = yr? \land x.report\_year = ryear? \land x.title = t? \land x.journal\_name = journal? \land$
$x.volume = vol? \land x.issue = jissue? \land x.issn = jissn? \land x.page\_range = pagerange? \land$
$x.doi = jdoi? \land x.url = jurl? \land x.file = doc? \}$
$\Rightarrow success! = RECORD\_SUCCESSFULLY\_ADDED$

Figure 2. Z schema for adding a journal into the system

Figure 3 shows a schema for listing records of journal article from RAMS. If there are no records matching a criterion, a message is displayed notifying that records are not found.

ViewJournal

Ξ *RAMS*
author? : *AUTHOR*
year? : *YEAR*
title? : *TEXT*
response! : *RESPONSE*
result!, *records* : *JOURNAL*

$records = (\mu x : Journal \mid x.authors = author? \lor x.title = title? \lor x.year = year?)$
$result! = records$
$\{records\} = \emptyset \Rightarrow response! = NO\_RECORDS\_FOUND$

Figure 3. Z schema for viewing journal articles

SYSTEM IMPLEMENTATION

Through a rigorous process, RAMS was implemented in close collaboration with the intended users who tested the components as they were developed and provided feedback that sometimes led to iterations on some components. Responsive technologies were engaged that enable the system to be accessed on a wide range of devices, including those with small screens. The system was mainly written in PHP in conjunction with JavaScript, Ajax and JSON embedded in the HTML5. It is comprised of simple and attractive interfaces that allow users to easily navigate the system and quickly accomplish their tasks.

The implementation of RAMS is based on the 3-tier client-server architecture organized in the presentation tier, application tier and data tier. The presentation tier comprised of all components that are responsible information presentation and visualization in a web user interface. It encompasses the web-browser based representation of all information that can be accessed in RAMS. Clients in the presentation tier send their requests over the HyperText Transfer Protocol Secure (HTTPS) to the web server that responds with the queried data over the same HTTPS to a client. The application tier comprised of all components that are responsible for the logistics of RAMS, such as a web server that communicates with the presentation tier and data tier to process the incoming queries and move data between the presentation tier and data tier. In short, application tier coordinates the application, processes commands, makes logical decisions and evaluates queries received from the presentation tier. The application tier was written in PHP and is capable of handling simultaneous connections that allow several users to interact with RAMS. The RAMS data tier is where information is stored and retrieved from MySQL database, passed to the application tier for processing and eventually to the presentation tier for viewing by the user. The RAMS data tier generally comprised of all components responsible for the persistent, sustainable storage and management of data. Figure 4 shows the simplified 3-tier client-server architecture of RAMS.

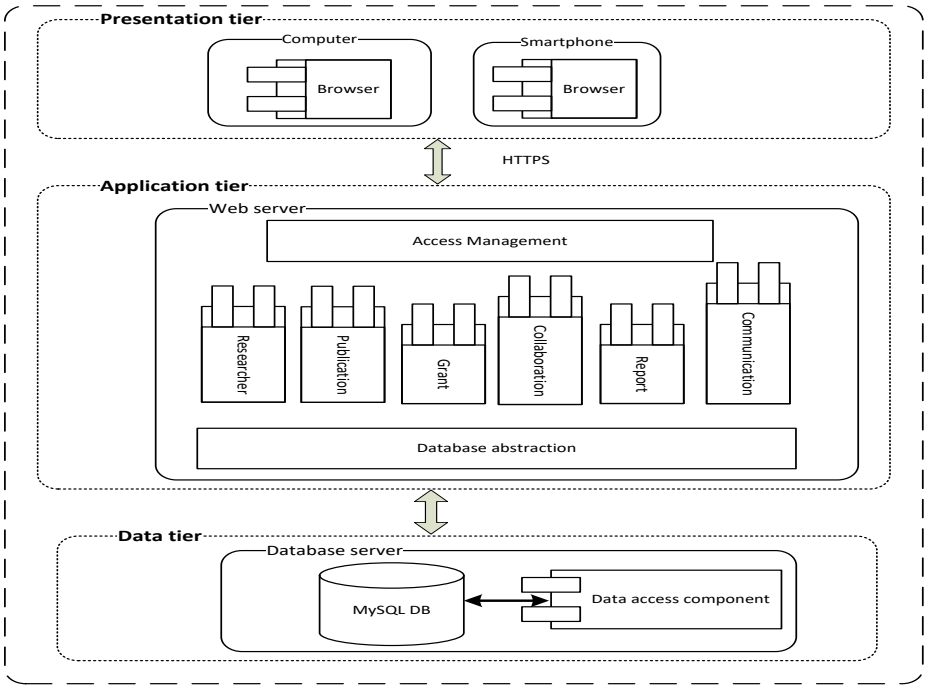

Figure 4. Client-Server architecture of RAMS

Figure 5 shows the login screen of RAMS while Figure 6 shows the login screen when viewed on small screen sized mobile phone. Figure 7 shows a screen populated with the results of querying the system to search the database of journal publications.

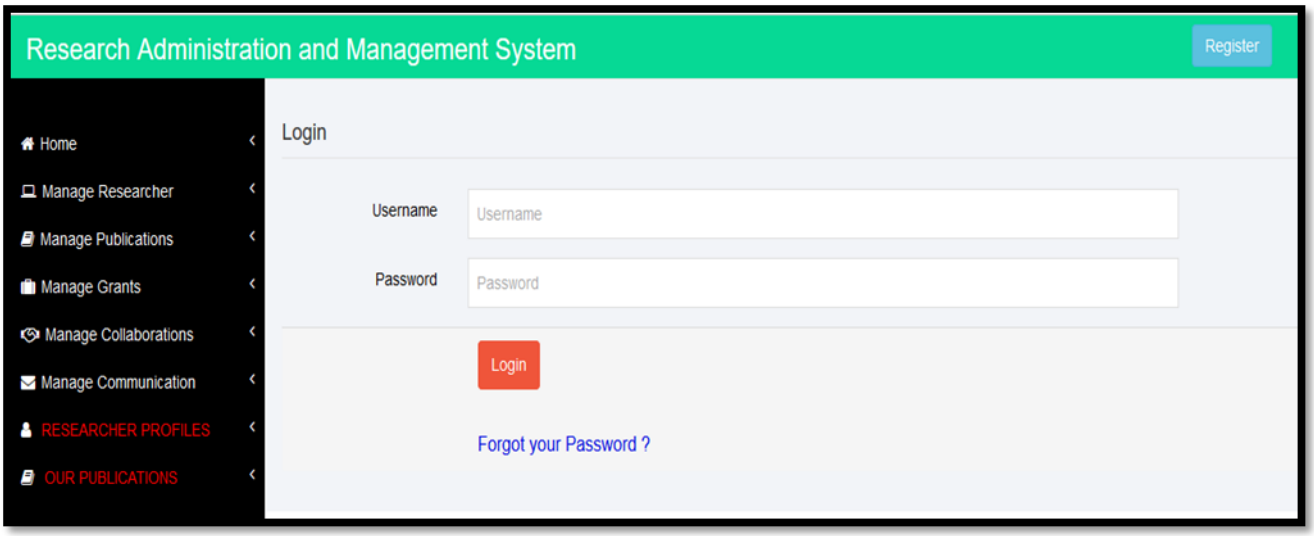

Figure 5. Login screen when viewed on PC

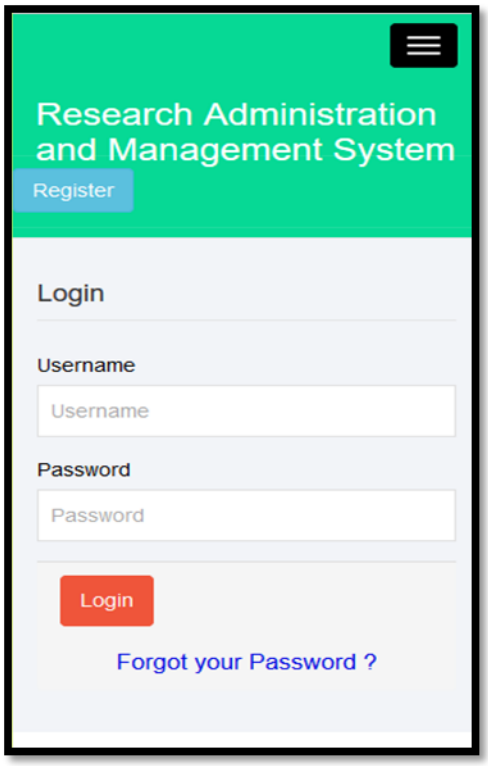

Figure 6. Login screen on mobile phone with smaller screen size

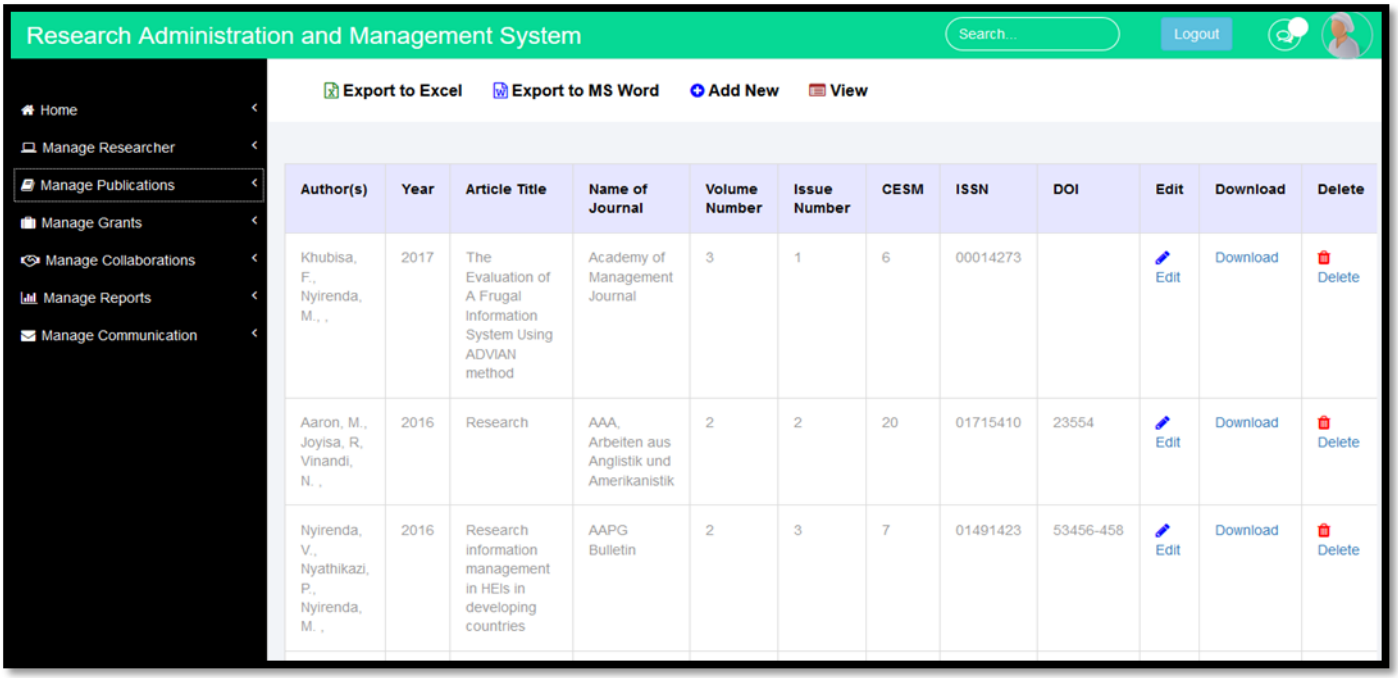

Figure 7. Screen showing journal publications queried from the system

SYSTEM EVALUATION

The evaluation of a design artifact is a key activity in the design science research because it provides feedback for further improvement, development and assures the rigor of a research (Venable et al., 2016). It provides an answer to the crucial question of "how well the artifact performs?" (Shrestha et al., 2014). System evaluation helps to establish that an artifact worked or did not work, to determine how and why it worked or not (Pries-Heje et al., 2008). It is crucial, it provides feedback and better understanding of the problem in order to improve both product quality and design process" (Hevner et al., 2004). A key purpose of design science research evaluation is to determine whether or how well the developed artifact achieves its ultimate purpose (Venable et al., 2012).

The study reported in this paper follows the naturalistic usability evaluation of RAMS that involves observing the system performance in the real environment and engaging real users to accomplish authentic tasks (Venable et al., 2016; Olugbara & Ndhlovu, 2014; Venable et al., 2012; Pries-Heje et al., 2008). The concept of usability is defined as "the extent to which a product can be used by the specified users to achieve desired goals with effectiveness, efficiency and satisfaction in a given context of use" (Aziz et al., 2013). It is one of the essential quality characteristics that are considered for evaluation in information systems and is central in the context with highly heterogeneous user groups as it is the case in developing countries (Teka et al., 2017). It has resulted into various instruments been developed for evaluating the usability of a system in different usability dimensions. For instance, Olugbara et al. (2010) developed the effectiveness and user satisfaction questionnaires that they used to measure the usability of a location-based shopping assistant recommendation technology. In their questionnaires, two usability dimensions are effectiveness and satisfaction. Lund (2001) developed the user satisfaction and ease of use (USE) questionnaires for measuring system usability in four usability dimensions of usefulness, ease of use, ease of learning and satisfaction. Recently, Parhizkar & Commuzi (2017) evaluated the usability of their tool in four dimensions of usefulness, ease of use, ease of learning and

satisfaction. More recently, Joshi et al. (2019) considered five measures of learnability, efficiency, memorability, error and satisfaction for impact of usability on process lead-time in information systems. Kortum & Sorber (2015) mentioned several other popular instruments for evaluating system usability and they used the SUS questionnaires (Brooke, 1996) in their work.

The usability evaluation instrument in this study considered five usability dimensions of effectiveness, usefulness, ease of use, learnability and satisfaction borrowed from Joshi et al. (2019); Parhizkar & Commuzi (2017); Olugbara & Ndhlovu (2014); Olugbara et al. (2010) and Lund (2001). Effectiveness is defined as the performance in accomplishment of tasks by some percentage of users within the system (Thuseethan et al., 2014). Usefulness is concerned with how good an information system is to achieve some desired goals (Roger, 2011). The ease of use ties in with the assessment of the mental effort of a person involved in using an information system and it determines how easy the system is to use (Downing & Liu, 2014). Learnability is concerned with the ease with which new users can begin effective interaction with an information system and achieve maximal performance (Munaiseche & Liando, 2016). Satisfaction measures if users feel comfortable or pleased with using an information system (Pruett & Choi, 2013). It was determined that in conforming to the usability definition (Aziz et al., 2013), a better understanding of the usability of RAMS could be obtained from the intended users in a real environment. Consequently, users were selected to experiment with RAMS and provided feedback to validate the system usability in the enunciated five dimensions.

This study engaged the service of twenty users who registered and experimented with the RAMS to evaluate its usability. These users were in two categories of researchers and staff from the Research and Postgraduate Office at DUT. These included 15 researchers who were randomly selected, but have had experience using the current research information system and 5 staff from the Research and Postgraduate Office. The five staff from the Research and Postgraduate Office were chosen because they are the ones who collect and input data on publications into the current research information system and produce the relevant reports. The researchers were chosen because they also provide their information into the system and play a critical role in the research process. Moreover, their experience with the use of the current research information system was considered important. Initially, a training session was provided to all the evaluators to acquaint them with how the new system works. The five evaluators from the Research and Postgraduate Office were trained in the boardroom within the Research and Postgraduate Office after which they were asked to enter at least two publications of each type and produce reports from the system. On the other hand, researchers were trained individually as it has proved difficult to assemble them together because of their busy schedules. Hence, different training sessions with the fifteen researchers were conducted at their convenient time. After each training session, each researcher was requested to individually experiment with the system by entering information about their publications, at least two journal articles, two books, two book chapters and two conference papers. The evaluators from both categories were requested to rate the usability of the system after they had experimented with it using the questionnaires presenting 20 items on a semantic differential scale of 1 to 5. In the context of this work, 1 means “Strongly Disagree” and 5 means “Strongly Agree", where intermediary values indicate the intensity of agreement as shown in Table 2.

EVALUATION RESULTS

The mean, standard deviation (STDEV) and coefficient of variation (CoV) statistics have been used to explain the usability evaluation results. In particular, CoV provides an easy to interpret a measure of dispersion of usability dimension and it is the ratio of STDEV to mean expressed in percentage. The prime reason we prefer CoV to the conventional mean and STDEV is that it can establish a comparison

across different usability dimensions, which are now evaluated on a common relative scale. The lowest CoV value of 0 indicates that evaluators responded excellently to an item of a dimension while the CoV value of 100 indicates that evaluators responded poorly to an item of a dimension. Table 2 shows the usability evaluation results, which generally indicate that most evaluators responded positively to the statements attesting that RAMS is usable. In addition, the results show that RAMS addresses relevant challenges of research information management in HEIs. Evaluators faithfully judged that RAMS could be a suitable solution to the challenges of research information management that are often encountered at the DUT and other HEIs with similar requirements. Nevertheless, the results show that a small percentage of evaluators provided unsatisfactory feedback. This was expected because at the time of testing, some of the system components were still under development. It is anticipated that those components will be integrated into the system as soon as they are realized.

Table 2. System usability evaluation results

It= Item no Strongly Disagree = 1 Strongly Agree = 5

	Criteria	**Percentage response to item**					**Statistics**		
It	**Effectiveness**	1	2	3	4	5	**Mean**	**STDEV**	**CoV**
1	I needed much help to use the system.	60%(12)	20%(4)	10%(2)	10%(2)		1.67	1.08	64.67
2	I found the system difficult to use despite help received.	70%(14)	25%(5)	5%(1)			1.33	0.59	44.36
3	I found the provided features of the system well integrated.		5%(1)	5%(1)	30%(6)	60%(12)	**4.60**	**0.60**	**13.04**
	Usefulness	1	2	3	4	5			
4	The system is useful.		5%(1)	10%(2)	20%(4)	65%(13)	4.40	0.90	20.45
5	The system makes the things I want to accomplish easier to get done.		5%(1)	20%(4)	20%(4)	55%(11)	**4.40**	**0.80**	**18.18**
6	The system does everything I would expect it to do.		5%(1)	20%(4)	35%(7)	40%(8)	4.20	0.90	21.43
7	The system saves me time when I use it.			20%(4)	40%(8)	40%(8)	4.30	0.80	18.60
	Ease of use	1	2	3	4	5			
8	The system is easy to use.		5%(1)		30%(6)	65%(13)	4.60	0.80	17.39
9	The system is simple to use.		5%(1)		30%(6)	65%(13)	4.50	0.80	17.78
10	The system is user friendly.		5%(1)		30%(4)	65%(13)	4.50	0.79	17.56
11	The system requires the fewest steps possible to accomplish what I want to do with it.			5%(1)	50%(10)	45%(9)	**4.40**	**0.60**	**13.64**
12	Using the system is effortless.	5%(1)		10%(2)	35%(7)	50%(10)	4.40	0.70	15.91
	Learnability	1	2	3	4	5			
13	The system is easy to remember how to use.	5%(1)		15%3)	25%(5)	55%(11)	4.28	1.07	25.00
14	I learnt to use the system quickly.	5%(1)		5%(1)	15%(3)	75%(15)	**4.56**	**1.04**	**22.81**
15	The system is easy to learn to use.	5%(1)		5%(1)	25%(5)	65%(13)	4.45	1.04	23.37
	Satisfaction	1	2	3	4	5			
16	I am satisfied with the system.	5%(1)	5%(1)	5%(1)	35%(7)	50%(10)	4.33	1.03	23.79
17	The system interface is simple to use.		5%(1)		35%(7)	60%(12)	**4.45**	**0.79**	**17.75**
18	The system works the way that I expected.		10%(2)	20%(4)	25%(5)	45%(9)	4.20	0.90	21.43
19	The system is pleasant to use.		5%(1)	5%(1)	25%(5)	65%(13)	4.50	0.90	20.00
20	I would recommend the system to other users.		5%(1)	10%(2)	10%(2)	75%(15)	4.50	0.92	20.44

DISSCUSSION

In this study, three research questions have been investigated in order to contribute to the current literature on research information management. These questions focus on the challenges of research information management, characteristics of an ideal research information management system and perceptions of users on the usability of a developed research information management system. Current literature suggests several challenges of research information management, including data preservation, lack of resources, policies, coordination, aggregation, standardization, harmonization, integration and communication between various stakeholders (Biesenbender, 2018; Riechert et al., 2016; Curdt & Hoffmeister, 2015; Quix & Jarke, 2014; Scholze & Maier, 2012). The issue of standardization, particularly appears to still be a dominant challenge of research information management (Biesenbender, 2018). Moreover, literature suggests that different approaches and mechanisms are used to collect, curate and manage research information (Stvilia et al., 2018a; Bian et al., 2014; Gaspar et al., 2013; Chudlarský & Dvořák, 2012; Ghvedashvili et al., 2011; Zhang et al., 2009). However, little is known about what constitutes an ideal research information management system whose understanding can help to improve the performance of current systems. In particular, comparative analysis and usability evaluation appear to be promising endeavors that could culminate in the understanding of an ideal research information management system.

The current study has addressed the identified gaps by engaging literature study to uncover the critical challenges of research information management in HEIs with particular emphasis on developing countries. The application of DSRM with the use of a formal method for requirements specification has helped in the development of a web-based research information management system for HEIs in developing countries. The usability of the system has been validated in a practical case study setting. In this study, we found that an ideal research information management system posses interesting features such as compliance with global requirements of various stakeholders, flexibility to accommodate changing requirements with minimal maintenance cost. The system should be web-based and platform independent to facilitate accessibility and easy interaction with end users. It should be effective in terms of well integrated features, easy to accomplish a task and its interface should be simple to use. This study makes significant contributions to research and practice.

Implication for Research

This study adds to prior works (Bian et al., 2014; Gaspar et al., 2013; Chudlarský & Dvořák, 2012; Ghvedashvili et al., 2011; Zhang et al., 2009) on research information management by developing a web-based research information system as an important contribution to the challenges of research information management (Kabigwu et al., 2016; Cox et al., 2014; da Silva et al., 2014; Williams & Hardy, 2011). It shows through literature review that standardization still constitutes a significant issue in research information management (Biesenbernder, 2018). In an attempt to provide a good understanding of standardization issue, a case study was carried out, involving real users who evaluated the usability of the developed system. Literature on usability evaluation has suggested that user involvement and participation has positive impacts on the system implementation success (Teka et al., 2017). Moreover, it suggests that user involvement and usability evaluation are core principles of user centric design (Teka et al., 2017). However, future work on research information management system should focus on standardization that currently remains unresolved.

The usability evaluation results of this study contribute to the prior research on the significance of systematic evaluation in DSRM (Hevner & Chatterjee, 2010; Peffers et al. 2007). This stream of research has emphasized that the frequent failure of information systems is generally the lack of

adequate capturing of system requirements (Schneider et al., 2016). The usability findings of this study lend detailed insight into the functionalities that the system must provide to end users to accomplish their tasks effectively, easily and with a high level satisfaction (Joshi et al., 2019). In fact, research has been engaged successfully in providing reasons that insufficient communication between diverse stakeholders in the design process is one of the main challenges for none acceptance of the resulting system and a low motivation to provide data (Curdt & Hoffmeister, 2015). The current study suggests that based on the CoV values, the provided features of RAMS are well integrated (13.04%). The system supports users to easily accomplish their tasks (18.18%), it takes fewer steps to accomplish tasks (13.64%), it is quicker to use (22.81%) and its interface is simple to use (17.75%). The usability results reflect on the usability of RAMS for research information management in the context of HEIs in developing countries.

Recommendation for Practice

The direct intrinsic implication of the findings of this study is that regular involvement of users in the system development can increase their satisfaction with the system. In addition, it can enhance the understanding of developers on what constitutes an ideal system. For example, collaboration between researchers, developers and system users can be mirrored to facilitate requirements alignment. The study emphasizes the importance of research information management and using cost-effective web-based systems to facilitate research information management. It emphasizes that research information management systems should be designed, taking cognizance of the important issues of user involvement (Teka et al., 2017), requirements specification (Schneider et al., 2016) and usability evaluation (Venable et al., 2016).

Although this research was limited to a case study of a single HEI, RAMS can be used in other HEIs with similar requirements. This single case study served the purpose of building on a little understood phenomenon based on a specific revelatory case and maximize what can be learned in the period of time available for the study. Moreover, since RAMS is not a proprietary system, modifications can be made to it to accommodate the requirements of a specific higher education institution. This is possible because the system encompasses the essential open and standard metadata for research information management. RAMS can integrate research information from different HEIs and can be managed centrally, while allowing research managers of different HEIs to still be able to generate the required reports that are specific to their institutions.

More importantly, this research design did not aim for generalization into all other settings of HEIs. Instead, it is aimed for creating an understanding of what should constitute an ideal research information management system in the context of HEIs in developing countries with analogous requirements. In particular, while the system typically does not claim generalization to all educational contexts, the resulting system should be adaptable to other contexts. What this means is that we do not claim that RAMS is absolute, perfect or is a final product. We want to encourage fellow researchers to pick up on this system and particularly its refinement to achieve complete standardization. We are desirous to welcome future studies to provide extensions to RAMS based on unseen aspects and refinements of the present dimensions. Although this specific case study was revelatory regarding the misalignments of many existing similar systems, we acknowledge these elements as boundaries to our research. Instead of claiming generality, we hope to provide rich, valuable and detailed insights into settings where multiple researchers need to collaboratively create a single near ideal software product for managing research information in the context of HEIs in developing countries. Future research should therefore pay close attention to the software and data architectures of a near ideal research information management system.

CONCLUSION

The purpose of this study is to develop a usable web-based research information system in collaboration with real users and test its usability in the context of HEIs in developing countries. In this paper, we have described such a system that can help to address pertinent challenges associated with research information management in the context of HEIs in developing countries. The usability evaluation of the system indicates that it is effective, useful, easy to use, learnable and satisfactory to real users. Research information management will tremendously benefit researchers and other stakeholders in the medium to long term. It is important to strongly emphasize that any investment in infrastructure development, such as a reliable computing network to support the integrated storage and ubiquitous access to research data is practically essential. Equally essential is the implementation of an effective research information management policy to provide guideline of best practices for researchers and stakeholders to emulate.

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