Deploying Design Science Research in Graduate Computing Studies in South Africa

Full Paper

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Abstract

Design science research is a relatively recent paradigm, which has enjoyed more acceptance in information systems than in computer science. Yet researchers are increasingly accepting this new paradigm where artifacts are to be developed to solve a problem, and the knowledge that is derived during the process is recorded and contributes to the field of knowledge. It is also particularly applicable in a developing world context. In this paper we present two case studies, demonstrating how two postgraduate students used design science research during their research. We reflect on the lessons learned and explain how design science research can be an attractive option for graduate student research at masters and doctoral level in both Information Systems and Computer Science.

Keywords

Design science research, information systems, computer science, masters, doctorate, case studies, practical/applied knowledge, developing context, South Africa

Introduction

Herbert Simon (1969) was one of the first people to suggest that design might be a scientific process. In the intervening years a number of researchers have attempted to rise to the challenge to work towards a systematic body of evidence towards a "*science of design*" (Van Aken 2009). Winter (2008) explains that design-oriented researchers, in Europe and elsewhere, are promoting a consistent methodology but are meeting with some resistance, with many claiming that design cannot be given scientific status. Winter furthermore argues for a concerted effort to put any knowledge gained into action in order to solve real-world problems. In the field of information systems a number of eminent professors signed a memorandum arguing for a design-oriented approach to information systems research (Osterie *et al.* 2010). There is clearly a need to strive towards developing rigorous standards for design in science.

Design science is a paradigm that deals with the *construction* of artifacts (similar to Simon's (1996) concept of the science of the artificial) as opposed to a behavioral sciences paradigm that deals with the behavior of humans as they *use* artifacts (March & Smith 1995). According to Hevner *et al.* design science research (DSR) allows a researcher to "*create and evaluate information technology (IT) artifacts intended to solve identified organisational problems*" (Hevner *et al.* 2004, p. 77). In DSR knowledge is obtained via the creation process, i.e. during the design process of the IT artifact. Vaishnavi and Kuechler (2015) now position DSR as a paradigm alongside positivism and interpretivism.

In this paper we will present two case studies to show how graduate IT students at two South African Universities have successfully applied the knowledge we currently have about design science. The first case study deals with Information Systems (IS) research where design science seems to enjoy the most attention. IS is a discipline that concerns the information that a computer system can provide to aid an organization in defining and achieving its goals, but also the processes that an enterprise can implement and improve, using IT. The other case study deals with Computer Science (CS) research where the scientific method is still the *de facto* research method. CS concerns designing and building software, to effectively solve computing problems, such as storing data in databases, sending data over networks, providing solutions to security problems, and addressing challenges in areas such as robotics and computer vision. By considering these case studies in different disciplines, we believe it will contribute towards Winter's call for standards in design science.

Design science in the South African context

DSR is well placed to facilitate the invention of technological artifacts with both a global and a more contextualized, local use-value to solve real-world problems. DSR can also bridge the divide between academic rigor and practical relevance (Naidoo *et al.* 2012) when developing models, conceptual frameworks, prototypes, and software for research projects, which is of increasing concern for many publicly funded universities in both developed and developing countries. Furthermore, DSR can address the contextual mismatch between where technology is developed and where it is used (Edgerton 2007) since it seeks to address the so-called design-actuality gaps (Heeks 2002), a situation that is prevalent in developing country contexts where technology that is adopted is often designed and developed primarily for use in developed countries. In South Africa, a country that encapsulates both *developing* and *developed* economies, contextual mismatches arising from design-actuality gaps, is a frequent occurrence.

According to the South African Department of Higher Education and Training's (DHET) White Paper on Post-School Education and Training (2013), "*The focus of policy must be on growing research and innovation, improving the quality of research, ensuring coherence of the policy frameworks guiding these areas across the higher education and research communities, and strengthening particular areas identified as important for national development*" (p. 34). There is thus a clear emphasis on the need for research to address national developmental needs, that is, real-world problems experienced by citizens of the country. According to the *National Development Plan 2030* the needs that should be addressed are many and varied. Amongst others there is a need to improve the economic infrastructure as a foundation of social and economic development, ensure environmental sustainability, establish an integrated and inclusive rural economy, improve the public health system, improve education, training and innovation, and build safer communities.

Against the above background, the next section covers two case studies of graduate research projects conducted using DSR at two South African higher education institutions. The first case study documents the development of a mobile health application to assist caregivers with capturing patient data in an underserved community for an IS Master's thesis at the *Cape Peninsula University of Technology* (CPUT). The second case study concerns a doctoral thesis in CS at *the University of the Western Cape* (UWC). In which a system to track hand trajectory and location was developed as part of an integrated sign and verbal communication mobile translation system for South African Sign Language.

Case 1: Masters research in Information Systems

Context of the study

The study, which dealt with a mobile health application for caregivers, formed part of a larger research project for which funding was obtained to investigate appropriate socio-technological methods for a developing context. Currently home-based healthcare in these contexts are still mostly paper-based. Four masters' studies were based on the work of the project team: An ethnographical study of the context of home-based healthcare that formed part of an anthropology masters (Van Zyl 2011); Service design challenges in home-based health care (Delen 2011); Indigenous knowledge and caregivers' use of data elements in home-based healthcare (Tswane 2013); and finally the study on which this paper is based that considered the design and development of a semantic metadata repository using design science research (Van der Watt 2012).

Much time was spent on understanding the context of home-based healthcare in a developing context. As such, it was important to involve the caregivers as active co-designers of the planned technological solution. The emphasis was on first understanding the work activities and tasks of the caregivers before commencing development. The student had no previous design experience and it was also the first time that he was exposed to co-design methods in a developing context. He participated in these sessions initially as observer but later as an active co-designer with the design masters student who facilitated the design sessions with the caregivers. This had a major influence on his approach to his own study to specifically consider the importance of *context* on the development of technology solutions in a developing context.

Application of the design science research methodology

Assumptions

DSR was chosen, as a research approach, because it was particularly suitable to conduct "practical" research by combining IS research with the process of design and development. It was important to understand what an appropriate design would be for the problem and also to learn from the design process. A pragmatic approach was indicated by the literature and DSR provides for applying theoretical knowledge in achieving a specific goal. At the same time the research approach was influenced by the context in that it requires a solution for a specific rather than a generic situation.

In this study the importance of the specific context and how the people respond to their circumstances influenced the choice of the ontological and epistemological assumptions. The research ontology is based on a nominalism stance from a subjective viewpoint to investigate how the caregivers interacted with their environment during their care service activities. These assumptions helped the researcher to better understand the problem in the work situation and more importantly to propose appropriate innovations for that context, e.g. caregivers still generally use feature phones and a solution using smartphones would not have been appropriate. Their level of education, digital literacy and work conditions were also considered to identify the objectives and focus of the study. The behaviour of the caregivers, and how they would potentially use the proposed IT solution, resulted in benefiting from both behaviour and DSR paradigms as being complementary rather than orthogonal, similar to Niehaves's (2007) view. This complementary view is supported by Purgathofer (2006) who regards analysis and synthesis as being fundamental to the design process to ensure that the problem is sufficiently understood.

The literature review was not able to identify any other studies that deployed DSR in a developing context. There was also no experienced researcher in DSR in the university to whom the researcher had ready access. The study commenced with the typical research structure, namely conducting a literature analysis (Chapter 2) on semantic repositories, ontologies and DSR followed by a research methodology discussion. A section on the ontological and epistemological stances was included, with a motivation for the assumptions used for the study (Van der Watt 2012). At this point it was not clear how to proceed with the rest of the thesis. The following points needed to be considered before continuing with the study since both the supervisor and student were using DSR for the first time:

- How to include the ethnographic study and co-design sessions in the DSR process?
- How to indicate the ontological and epistemological stances?
- How to structure the thesis?
- How to communicate the knowledge obtained during the design process and the knowledge about the different design concepts and IT artifact?
- How to evaluate the research, i.e. *ex ante* versus *ex post* evaluation?
- When to stop, i.e. after the proof of concept, working prototype or fully functional IT solution?
- How to deal with relevance versus rigor?

The above points were addressed by considering the different stages of the research methodology.

Research design around DSR

The student derived his own version of DSR methodology since he was interested to see how his research process and findings compared to the DSR methodology variations proposed by the literature. The DSR literature (Ellis and Levy 2010; Hasan 2004; Hevner *et al.* 2004; March and Storey 2008; Peffers *et al.* 2007) was reviewed to identify the different activities and to delineate similarities and differences. A DSR methodology was then designed to include the points that are specific to this research in the categories identified from the literature: research problem, objectives, knowledge search, conceptual design, design/development, test/evaluation, research rigor, communication, research contribution, practical use, product development. As a result, a framework with seven steps was created and used as the research methodology for this research considering all the points identified as important for this study (Van der Watt 2012) see Table 1.

STAGES	**DESCRIPTION**
1. Problem identification, understanding and motivation	This step involves the initial research (literature review) in order to better understand and motivate why the problem is important based on the gap identified in the literature. It also provides a motivation for using DSR as an acceptable research approach to address the identified problem.
2. Identifying the objectives/focus of the research and intended IT artifact	The artifact objectives are only identified in a situation similar to this research where the artifact/prototype's objectives and the research objectives are not the same but still related and both are relevant.
3. Concept design	In this step knowledge is gathered with the goal of conceptualising the intended problem space, generating the requirement of the solution and developing the solution concepts. This step also involves selecting between possible solutions if multiple solutions are presented.
4. DSR artifact design and development	In this step the design concepts towards the IT artifact are created. The artifacts are objects intended to both fill and intended practical purpose but are also knowledge-containing objects (containing logic, design decisions and assumptions).
5. Artifact evaluation	Evaluate the design and the prototype/artifact to ensure it solve the problem and meet the objectives, research rigor will be included.
6. Research contribution	The research contribution needs to be identified from the design and developed artifacts.
7. Communication	The results of the research are communicated to the intended audience, both as academic output, e.g. a thesis and practical guidelines for implementing and using the IT artifact. This step involves making choices around data presentation.

Table 1: Framework developed by student based on DSR literature consulted

Design and construction of the artifact

The student continuously moved between the design and development of the artifact and the data obtained through the research to adjust the design and development. The initial proposed solution had to be revised to cater for the actual context and, as a result, the design-actuality gap was dynamically addressed. The student also continuously consulted the literature. The design and development comprised three main components (1) concept design (general solution concept and solution internal concepts); (2) architecture construction, and (3) solution design and development (functionality and database and entity relational diagrams). The instantiation of the proposed design considered two main aspects: user interface (main menu, initiative, source type, source, metadata, relationship and visual metadata forms) and code class.

In designing the artifact the student relied on the research literature and also carefully reported his own observations and reflections of the actual situation and his interpretation of the process followed.

Evaluation

The design as a proof-of-concept was evaluated according to the following three aspects: metadata (appropriateness, statement of terms of use, long term management and metadata as a quality object); metadata repository (orientation, coverage and collaboration); and the use of the repository (example document, identification of data elements, repository content creation and repository usage evaluation).

The evaluation considered the underlying functionality and technical aspects of the artifact. The metadata model was evaluated with the most relevant NISO requirements as indicated in the literature (NISO Press 2004; Park 2009). The repository was measured along Thibodeau's (2006) axes for evaluating a digital repository. There were, however, no specific detailed criteria for quantitatively assessing the repository. The student therefore used the three axes for a qualitative discussion and evaluation.

The lack of standards for data elements within home-based healthcare is a well-known issue. Interoperability is therefore a problem but before that can be addressed the problem of different definitions, usages and interpretations of data elements in practice need to first be considered. This problem is even more complicated since the caregivers had to report and use data elements in English which is not their mother tongue. The findings from the study of the other graduate student (Tswane 2013), about indigenous knowledge and use of data elements, informed the design of the metadata repository for this study. The other graduate student became the user of the repository to establish whether it could be used to address the semantic problems at the user level.

How results were communicated

The thesis had the traditional format with an extensive literature analysis and research methodology in the first two chapters. The remainder of the thesis structure mirrored Table 1 above.

Feedback from the examiners/evaluators

The student was awarded the master's degree *cum laude* based on three external examiner reports. The international examiner reported that the research was extremely relevant, both globally and in South Africa. The need for research was well justified and research area actual. The examiner was impressed by how the potential methods were reviewed and their selection justified. The examiner commended the student whose own "voice" is visible throughout the thesis and evidenced by his understanding and the critical review of the research topic and methods.

Case 2: PhD in Computer Science

Context of the study

The PhD thesis being considered as an example of how DSR was used in Computer Science, forms part of a larger research project that deals with the development of an integrated sign and verbal communication mobile translation system for South African Sign Language (SASL) (Achmed 2014). Facial expressions, hand trajectory, hand location and hand shapes comprise the gestures of a sign language. Two of these aspects —hand trajectory and hand location—were the focus of this research.

The research made use of a single two-dimensional (2D) camera to track the hands of a sign language speaker as it is crucial to be able to track the hands even when other body parts, or the environment, occludes the hands. The student developed a framework to independently track the hands of a sign language speaker from a single 2D camera — in both constrained and unconstrained environments — without requiring any auxilliary devices apart from a cell phone camera. A constrained environment includes scenes that do not contain any background or foreground interference and where the background remains static, whereas an unconstrained environment might be, for example, an active outdoor location.

The designed framework comprised three phases: detection, tracking and learning. During the detection phase extended local binary patterns and random forests were used to validate that the object being tracked was indeed a hand. A data-association technique was used for the tracking phase, to track the hands independently. The learning phase used two algorithms (the scale-invariant features transform (SIFT) algorithm and the fast library for approximate nearest neighbors (FLANN) algorithm) to track and recover the hands if any form of tracking failure occurred, such as an intermittent occlusion.

Application of the design science research methodology

Assumptions

Crotty (1998) defines a methodology as "a strategy, plan of action, process or design lying behind the choice and use of particular methods …" (p. 3). Using this approach, DSR was applied as a methodology, which linked the choice of methods to the outcome of the research effort. The philosophical stance that informed the choice of methods was objectivism, which provided a basis for the quantitative research.

The study followed a positivist theoretical perspective thus was deductive with the emphasis on the testing of a theory (Bryman 2001). The DSR methodology provided the framework for the research and allowed the use of methods to objectively evaluate the tracking algorithms.

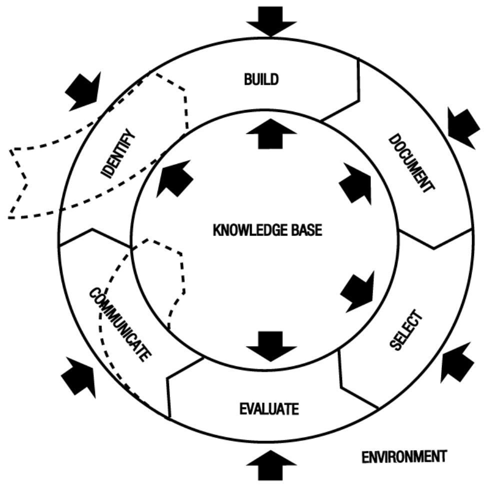

Figure 1: The design science cycle consisting of six iterative steps (adapted from Vom Brocke and Buddenick 2006, p. 582)

Research design around DSR

The student used the Vom Brocke and Buddendick's (2006) six-stage iterative DSR cycle to guide his research design (see Figure 1), namely:

1. Identify the needs and foundations of the requirements
2. Use the requirements to develop (build) an artifact that delivers the required functionality
3. Represent the software system and document it, including its limitations
4. Select evaluation criteria and methods
5. Evaluate the software system using the selected evaluation criteria and methods.
6. Communicate any additional requirements for a further iteration of the DSR cycle.

The researcher applied the methodology as three phases; for each phase a prototype was developed (see Figure 2) that was an extension (or a next version) of the initial artifact. Thus each phase entailed several iterations before the next phase was embarked upon. The final artifact was the "product" of this phased development.

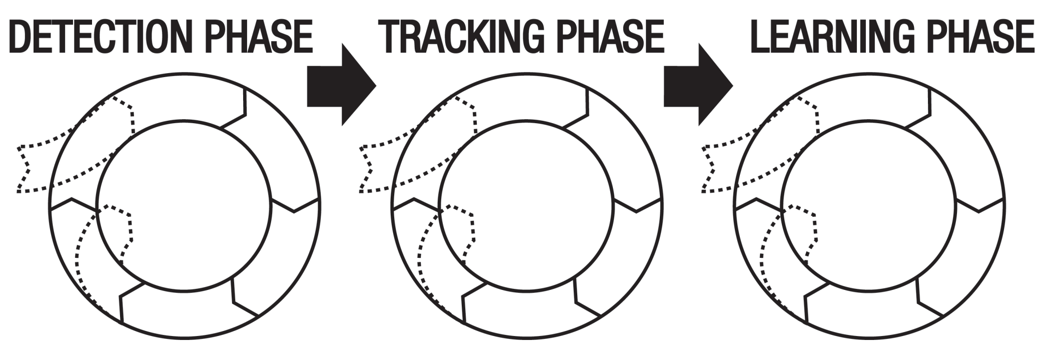

Figure 2: The DSR cycle applied to each development phase of the artifact (adapted from Achmed 2014, p. 41)

Design and construction of the artifact

The detection phase entailed the following components (or algorithms): local binary patterns (LBPs), random forests and support vector machine (SVMs). The tracking phase made use of a unique skin-segmentation algorithm and a data-association method that allowed multiple skin-colored objects to be tracked in both constrained and unconstrained environments. Finally, during the learning phase a context-based tracking approach, to recover the hands from tracking failure, was implemented.

Since tracking is fundamental and forms the basis of the research framework, it was engineered first and implemented as prototype T. Prototye T was followed by prototype DT where both detection and tracking were integrated into the framework. Finally prototype DTL was the integration of detection, tracking and learning phases.

Evaluation

Prototype T was developed to evaluate the framework for the tracking phase. The algorithm was designed to continuously track both hands independently in constrained and unconstrained environments. Here the hands were assumed to be in a certain initial position – thus it was not necessary to detect the hands. The aim of prototype DT was to add a hand-detection algorithm to the hand-tracking framework. Thus for each cluster in prototype DT the cluster had to be evaluated to determine if the cluster is a hand before it can be tracked. The aim of the final prototype DTL was to allow the system recover from failures by adding a learning phase algorithm to the hand-tracking and detection framework.

To evaluate the three prototypes, appropriate datasets had to be selected or compiled with enough variation to cover all the areas of interest. A dataset was compiled using a few SASL signed gestures—these covered the full variation of signs and were selected from the Fulton School for the Deaf SASL Dictionary (Howard 2008). Three categories of signs were selected: signs that use a single hand; signs that use both hands without occlusion; and signs that use both hands with occlusion. Some of these selected signed gestures performed the same movement but differed in terms of the hand shape. A data set was compiled using 20 individuals (with different body shapes, skin color and gender) to perform 30 selected signs — 10 from each of the 3 categories. These signs were performed in constrained and unconstrained settings resulting in a data set of 1 200 signed videos. Each video had an average number of 90 frames thus the data set contained a total of 108 015 frames.

A further dataset (of 16 000 images) was compiled to test the hand detection algorithm. It was made up of hand and non-hand images from data sets such as the Visual Geometry Hand Dataset, the Caltech 101 dataset and the Visual Geometry Group Hand Dataset. A subset of the dataset was used for training and the rest for testing.

To compare the prototypes, a standard pixel-level ground-truth tracking trajectory was used. The frames in each video were annotated by selecting the centre (represented by x and y coordinates) of each hand - this was stored as a text file in the same directory as the frames for each signed gesture. It was assumed that a hand was correctly located, if the result was not further than a radius of 20 pixels from the center of the hand.

How results were communicated

Results were communicated in terms of the three phases and presented as tables and graphs within the final dissertation. It was reported that the DTL prototype was a distinct improvement on the previous two prototypes.

Feedback from the examiners/evaluators

The external examiner applauded the fact that the expected scientific method was discarded in favour of a design science research methodology that was used to guide the student in this CS research. He noted that *"it allows a guided development and more honest approach to many modern research questions"*. He further noted that the use of DSR as a research methodology ensured that the research was carried out *"in a structured and reliable manner – with the side effect that the report of the results was structured"*. The reader of the dissertation could thus follow the reasoning behind the presented progressions. Furthermore the examiner was of the opinion that the material around the DSR evaluation of prototype solutions and its application in computer science education merited publication.

Discussion

In line with Gregor and Hevner's (2013, p. 339) view that "*a significant DSR program typically encompasses many researchers over several years*", the case studies reported here formed part of a larger research project. In Case 1 the student opted to refine a suitable DSR approach by combining existing DSR approaches. The other (Case 2) followed an existing DSR approach. Whilst developing an approach that is suitable for a particular context may be required to develop a more effective and efficient solution and can contribute to the methodological literature on DSR, care must be taken not to contribute to further fragmentation with respect to design theory (Dresch *et al.* 2015).

When comparing and contrasting the students' DSR approaches, the most notable difference between the two approaches is that the IS student used DSR to focus on his thesis layout (see Table 1) whereas the CS student applied DSR specifically for the construction/design of his algorithm. He also used the research design to communicate the experimentation process—which led to the "artifact"—to the reader of his thesis. Some aspects of the two approaches are similar (see Table 2). This is in line with the expectation that, "*The format for presenting a computer science/software engineering 'IT product' artifact will be different from that used with an IS 'socio-technical artifact' where an intervention in a social system (community or organizational) will have occurred*" (Niederman & March in Gregor & Hevner, 2013, p. 350). Lee *et al.* (2013) also differentiate between an IT artifact and an IS artifact, arguing that an IS artifact comprises technological, information and social artifacts. The two case studies presented bore out this distinction. Furthermore, as would be expected the doctoral study in the second case produced an artifact with a higher level of abstraction than the masters study in the first case study. However, as Gregor & Hevner (2013, p. 352) state, DSR results can often be presented effectively with artifact representations accompanied by a rigorous evaluation of the artifact in use and it is not necessary, nor even desirable, to present design theory.

THE 7 STAGES OF CASE 1	**THE 6 STAGES OF CASE 2**
Problem identification, understanding and motivation	
Identifying the objectives/focus of the research and solution	Identify the needs and foundations of the requirements
Concept design	
DSR artifact design and development	Use the requirements to develop (build) an artifact that delivers the required functionality
	Represent the software system and document it, including its limitations
	Select evaluation criteria and methods
Artifact evaluation	Evaluate the software system using the selected evaluation criteria and methods.
Research contribution	
Communication	Communicate any additional requirements for a further iteration of the DSR cycle.

Table 2: Comparing and contrasting the two DSR approaches

Ulibarri *et al.* (2014) suggest that, "*there is a demand for graduate training to more explicitly treat students' intellectual needs in tandem with their emotional needs to create happy, productive researchers*." In the first case, the student suggested DSR to his supervisor after reviewing methodological literature relevant to the construction of an IT artifact. The student was able to apply DSR to his study based on his interpretation of the literature—embracing DSR fully. DSR is now not only an accepted, but also the preferred, methodology at CPUT for graduate studies in IT[i]. Moreover, the activities around DSR have generated interest from the pure design disciplines: more design studies contemplate the design of IT artifacts from a design perspective and DSR provides a scientific alternative to the traditional design research approaches. In the second case the student was reluctant to deviate from the more traditional scientific method, the preferred method in CS research. At a *Design Development Research* symposium he was introduced to DSR and even though his co-supervisor thought that the description and use of DSR was superfluous, the student used it very effectively to frame and present his research.

Both these studies strove to bridge the gap between theoretical and practical knowledge as illustrated in Figure 3 (Ellis & Levy, 2010): the researcher applies practical knowledge of a situation or a task to create an artifact while at the same time generating prescriptive knowledge about the design process and characteristics of the design artifacts (Gregor *et al.* 2013). During the evaluation and reflection activities descriptive knowledge is generated (Gregor and Baskerville 2012).

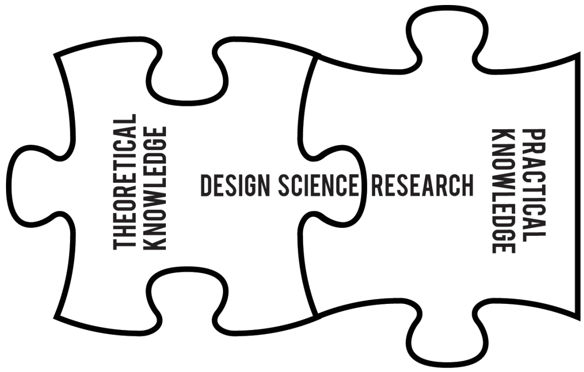

Figure 3: Design Science Research role in bridging Theoretical and Practical Knowledge (Ellis and Levy 2010)

This bridge between theoretical and practical knowledge echoes the discussion of Gibbons *et al.* (1994) and Nowotny *et al.* (2003) regarding two 'modes' of knowledge production and contribution. They identified and argued that there has been a shift of focus that higher education institutions may have to accommodate: from 'Mode 1' knowledge that focuses on knowledge produced within traditional disciplinary boundaries to 'Mode 2' knowledge which is application-oriented, trans-disciplinary, highly reflexive, socially distributed and subject to multiple accountabilities (Nowotny *et al.* 2003).

Although the contribution of 'Mode 2' knowledge is debated in the academic community, the framework that DSR offers for producing both 'Mode 1' and 'Mode 2' knowledge may offer a suitable synthesis of the two points of view. Furthermore, the ability to combine the theoretical and practical knowledge producing both 'Mode 1' and 'Mode 2' knowledge is particularly suited to the South African context where higher education institutions and researchers are expected to contribute concretely to achieving national development goals.

Finally, in their survey about DSR amongst computing faculty in South Africa, Naidoo *et al.* (2012) reported that supervisors perceive external examiners to be critical of DSR, which is one of the reasons deterring them from suggesting this approach to their research students. From these case studies it is evident that DSR can be used with great success at graduate level at both masters and doctoral level and in IS and CS to conduct research that is not only accepted by external examiners but is enthusiastically supported for its relevance, applicability and value.

Conclusion

Our case studies demonstrate that DSR can be used successfully by graduate students to design IT artifacts at both masters and doctoral level and in IS and CS. In both cases the research focus added value to the design process to ensure that designs are not merely *ad hoc* solutions to problems. It ensured that the design process gives due importance to the characteristics of the designs and the design process and contributes to the body of knowledge. However, the scope of application of the artifact, the level of abstraction, and contribution to (design) theory can be expected to differ between the degree levels and the disciplines. At the same time, care must be taken not to further fragment design theory methodology when developing suitable approaches in a particular context. Guidelines on adapting approaches for DSR will support students and supervisors and answer Winter's (2008) call for a *consistent* methodology.

The ability of DSR to produce both 'Mode 1' (theoretical) and 'Mode 2' (practical/applied) knowledge makes it ideally suited to contexts where higher education institutions and researchers are expected to contribute to the achievement of national development goals. Although these case studies have shown that DSR can be used successfully in a developing country context more studies are required to obtain greater insight into the use of DSR in a developing context especially where the aim is to improve a situation for people in underserved contexts. In such cases it is important to include developmental studies to ensure that IT artifacts are introduced in such contexts with responsibility.

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[i] Restructuring of the South African public university system between 2000 and 2005 resulted in three different types of higher education institutions: traditional universities, universities of technology, and comprehensive universities. UWC is a traditional university whilst CPUT is a university of technology. Traditional universities offer various academic and professional bachelor degrees, usually 3 years in duration, and a small number of diplomas and certificates at the undergraduate level. Graduate degrees comprise honors (a 1-year degree following the three-year Bachelor degree), masters and doctoral degrees as well as a limited number of graduate diplomas and certificates. Universities of technology offer a number of vocationally oriented undergraduate diplomas as well as Bachelor of Technology degrees. Graduate study at universities of technology is limited to a relatively small number of masters and doctoral programs (Ponelis *et al.* 2012).