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An Analysis of Design Science Research Adoption in Doctoral Projects in Australia

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Abstract

In the Information Systems (IS) discipline, Design Science Research (DSR) is distinctive; creating knowledge through the design of novel or innovative artefacts, and analysing the artefacts' use or performance. We present an analysis of DSR doctoral theses published in Australia for the period 2006-2017. Our purpose is to understand the extent and diversity of DSR applied by the Australian IS community in particular by doctoral candidates. We selected the theses from the Australian national repository and analysed their content. The findings suggest that 1) DSR is evolving and maturing in this cohort, 2) DSR theses have resulted in various artefacts and scholarly publications, 3) candidates' ability to theorize about their work remains a challenge, and 4) nomenclature in DSR remains a problem and the whole IS community should strive for consistency. This paper contributes towards our understanding of DSR as a research approach and offers recommendations to the DSR community.

Keywords Design Science Research, Doctoral Research, Research Methods, Australia

1 Introduction

Design science research (DSR) is recognized as an important and legitimate Information Systems (IS) research paradigm (Gregor and Hevner 2013). DSR is essential for information systems (IS) research because a considerable subset of IS research is focused on designing artefacts. Furthermore, DSR has been promoted as an approach to improve the rigor and relevance of IS research (Hevner et al. 2004). A recent review of papers in seven major IS journals revealed that although DSR had been one of the methodologies "receiving the least traction" in IS, it has shown "phenomenal" emergence from 2004-2013 (Palvia et al. 2015).

Despite the widespread recognition, DSR has not yet attained its full potential impact due to "gaps in the understanding and application of DSR concepts and methods", thus "ongoing confusion and misunderstandings of DSR's central ideas and goals are hindering DSR from having a more striking influence on the IS field" (Gregor and Hevner 2013).

Following a general trend in recognition and acceptance of DSR in the IS field, the adoption of a DSR approach in postgraduate studies has become more acceptable (Kotzé et al. 2015). However, concerns have been raised that design science research (DSR) may not be an attractive paradigm for the junior researcher (Österle et al. 2011) and that junior researchers might be advised to avoid DSR if it requires theory development and testing, rigorous artefact design, demonstration and evaluation (Peffers et al. 2014). One possible reason for students' reluctance to use DSR can be the time limitation since "a significant DSR program typically encompasses many researchers over several years" (Gregor and Hevner 2013). Students are important clients for the IS discipline because their tuition and fees directly contribute resources to the discipline, and in return, they should be provided with knowledge and expertise needed for gainful employment in the industry (Gill and Bhattacherjee 2009). In addition, some doctoral students will become the future-generation of academics; thus the quality and rigor of doctoral education is essential for the future of this discipline.

While the IS community is increasingly international, different regions might display different research approaches and interests (Stein et al. 2016). For instance, in spite of the limited number of DSR studies in top IS journals (Palvia et al. 2015), analysis of 10 years of publications in the European Conference on Information Systems (ECIS) showed that DSR has increased its share among research methods from just over 10 percent in 2003 to 25 percent in 2012 (Stein et al. 2016).

Although various researchers have analysed the publication of DSR journal and conference papers (Amrollahi et al. 2014; Arnott and Pervan 2012; Arnott and Pervan 2014; Deng et al. 2017; Herwix and Rosenkranz 2017; Indulska and Recker 2008; Leukel et al. 2014), to date little attention has been paid to the work undertaken by higher degree research (HDR) candidates. In other words, despite more than a decade since the publication of the seminal paper by Hevner et al. (2004), that resulted in a significant growth in DSR popularity among IS researchers, the experience of research students that adopted DSR is still not well documented (Kotzé et al. 2015) and the feedback for improvement of DSR theory and guidelines is lacking. To address this gap, we seek to answer the following research questions:

RQ1. What is the extent of DSR adoption among doctoral candidates in Australia?

RQ2. What are the outputs of Australian doctoral DSR theses?

The objective of this paper is to report on the state of DSR within Australian higher education. To achieve this objective, we undertake a document analysis of published DSR doctoral theses and apply content analysis to extract some of their key characteristics.

IS researchers in Australia have shown significant interest in DSR. According to research conducted by Indulska and Recker (2008), Australia was the third largest contributor (after USA and Germany) to global DSR in five top AIS-sponsored IS conferences, namely ACIS, AMCIS, ECIS, ICIS and PACIS, from 2005-2007. Thus, in spite of the delimitation of our study to Australian doctoral DSR theses, the findings can provide insight to the wider IS research community. In addition, our work provides a basis for future studies to compare use of DSR in different geographical locations.

This paper is divided into six sections. In the next section, a summary of prior research on review and assessment of DSR publications (papers and theses) is provided and various classifications of DSR artefacts in the reference literature are synthesized to establish a basis to analyse DSR theses and identify their key characteristics. This leads to a description of the approach we took to analyse Australian doctoral theses. In section four, the results of the analysis are presented. In the discussion section, the research questions are answered and key issues are raised, followed by recommendations

for candidates and supervisors. The conclusion provides a summary, limitations of our research and an agenda for future work.

2 Theoretical Background

2.1 Classification of design science research artefacts

Four types of artefacts were proposed by March and Smith (1995) and we adopted the guidelines presented in Hevner et al. (2004): construct (a conceptualization used to describe problems within the domain and to specify their solutions), model (a set of propositions or statements expressing relationships among constructs), method (a set of steps used to perform a task), and instantiation (the realization of an artefact in its environment which operationalizes constructs, models, and methods). More recently, theorizing is seen as an important output in DSR as promoted by Gregor and Jones (2007) and theory included as a possible DSR artefact (Winter 2008). Peffers et al. (2012) developed a taxonomy of artefact types by reviewing 148 design science papers in information systems and computer science. Their taxonomy includes framework (described as meta-model) and algorithm in addition to the four artefact types proposed by March and Smith (1995), whereas Gregor (2006) considers frameworks as a type of theory.

IS scholars stress the difference between professional design and design science research, and have argued that DSR "should produce important and interesting contributions to both IS theory and practice" (Arnott and Pervan 2012). Similarly, Hevner et al. (2004) argued that this contribution to an existing body of knowledge is what separates design science research from design practice. Different opinions have emerged among DSR scholars with regard to emphasis on design theory as a product of DSR research. Gregor and Hevner (2013) identified a *design-theory camp* (e.g.Gregor and Jones 2007; Walls et al. 1992; Walls et al. 2004), and a *pragmatic-design camp* (e.g. Hevner et al. 2004; March and Smith 1995) with the two camps placing comparatively more emphasis on design theory or artefacts respectively as research contributions. Further, Gregor and Hevner (2013) suggested a complementary approach that acknowledges different forms of contributions as acceptable theoretical contributions of DSR. These contributions can range from "strong theory", to "partial theory, incomplete theory, or even some particularly interesting and perhaps surprising empirical generalization in the form of a new design artifact" (p. 339).

2.2 Prior reviews of DSR papers

A number of studies have reviewed published papers that used the DSR approach and have assessed their rigor and relevance. In a review of 14 top-ranking journals, Amrollahi et al. (2014) found that more than half the DSR papers reported empirical studies that focused on artefact development aimed to solve soft business problems (e.g. making IT investment decisions), technology problems (e.g. algorithms) and system development problems. Amrollahi et al. (2014) found the most frequent artefact type reported was method (49%); followed by model (24%), IT artefact (15%), and finally theory (12%). This distribution is reasonably consistent with the findings from the review of Business & Information Systems Engineering (BISE) journals and conferences conducted by Leukel et al. (2014): method (59%), model (25%), instantiation (10%), and construct (6%). Indulska and Recker (2008) reviewed 83 papers published in five top AIS-sponsored IS conferences in the years 2005-07 and identified process modelling, knowledge and information management as the most prevalent areas of study. Their study revealed that the way DSR was conducted did not fully align with Hevner et al.'s (2004) guidelines and they called for further guidance on DSR.

A review by Leukel et al. (2014) of publications authored by BISE researchers in the German speaking countries found a tendency for DSR to focus on managerial problems, particularly strategic decision making at the organizational level.

Adoption of DSR in Decision Support System (DSS) research has been increasing over the past decade (Arnott and Pervan 2014). Arnott and Pervan (2012) employed Hevner et al.'s (2004) seven guidelines to assess the use of DSR in the DSS research. Their assessment of 362 DSS design-science research papers published between 1990 and 2005 in 14 journals revealed major issues in the DSR-based DSS literature, viz. research design, evaluation, relevance, strategic focus, and theorizing. The distribution of the developed artefacts was instantiation (66.4%); method (26%); model (7.1%); construct (0.5%). However, Arnott and Pervan (2012) argued that the reported instantiations may embody a construct, model, or method. Due to the lack of guidance on how to assess or categorize relevance in Hevner et al.'s (2004) guidelines, Arnott and Pervan (2012) assessed the relevance of their sample papers using Anthony's (1965) categorization of management activities: strategic, operational, and tactical. They concluded that only 10.5 percent of the papers had a strategic focus. They also found that "only a

surprisingly small 2.4 percent of DSS design-science projects have made contributions to the theory focused areas of design foundations and methodologies" (Arnott and Pervan 2012).

In a more recent review of DSR papers published in the IS basket of eight and four IS conferences in the period 2001-2015, Deng et al. (2017) identified 278 DSR publications (70 journal articles and 208 conference papers). Deng et al.'s analysis showed an upward trend in the number of publications during this period, with a surge in the publication rate from 2007 onward. The distribution of the developed artefacts in these 278 papers was as follows: method (44.5%); instantiation (27.5%); model (16%); theory (10.6%); and construct (1.4%).

In another study, Herwix and Rosenkranz (2017) reviewed DSR papers published in the IS basket of eight from 1977 to 2016. Based on the co-citation analysis of the 93 journal articles identified in their study, Herwix and Rosenkranz (2017) concluded that "DSR is still an emerging paradigm with research about DSR being relatively isolated from other research areas so far" (p.168).

These reviews of published DSR papers have raised concerns related to the rigor of DSR studies and called for further work on theoretical and methodological underpinnings: DSR theoretical foundations of artefacts have not been well-articulated; use of terminology is inconsistent; and there is poor conformance to DSR guidelines for artefact types and evaluation (Indulska and Recker 2008; Leukel et al. 2014).

2.3 Prior reviews of DSR in doctoral studies

We found only two studies both of limited scope that investigated the use of DSR in doctoral studies. Kotzé et al. (2015) used a questionnaire survey to investigate the use of DSR by nine IS doctoral students in South Africa. Their study focused on the topics of the theses, the artefacts produced, the research designs followed, the motivation for selecting DSR and the students' experience in using DSR. The developed artefacts were reported as one construct, three methods, seven frameworks and one instantiation. Kotzé et al. (2015) found Hevner et al.'s (2004) four-type taxonomy of artefacts to be limited for categorization of the artefacts, and added the framework type. Kotzé et al. (2015) found that the cyclic nature and the relevance aspects when developing artefacts were the strengths of the students' DSR theses, but the philosophical underpinnings were weak.

In the second study, Venter et al. (2015) presented the findings from their assessment of *two* theses that used DSR (one masters thesis in Information Systems and one doctoral thesis in Computer Science) conducted at two South African higher education institutions. The most notable difference between the two approaches used by the two students was that the IS student used DSR to focus on his thesis layout whereas the computer science student applied DSR specifically for the construction/design of an algorithm and also used the research design to communicate the experimentation process to the reader of the thesis. Venter et al. (2015) echoed Winter's (2008) call for a consistent DSR methodology and the need for DSR guidelines that support students and supervisors.

3 Research method

The method to analyse Australian Doctoral DSR theses comprised five steps: 1) identify resources; 2) select DSR theses; 3) develop checklists to assess theses; 4) extract data from theses; and 5) synthesize extracted data. These steps were adapted from advice to conduct systematic literature reviews (Kitchenham and Charters 2007).

Step 1. Identify Resources. All Australian Universities are requested to maintain a digital repository of higher research degree theses produced by their candidates and most mandate electronic submission of digital theses. As a result, the full text of most theses is made available on open access via the institutions' library web sites and links are recorded in the National Library of Australia's online repository *Trove* (NLA 2015).

Step *2. Select DSR theses.* To select the theses to review, we established search criteria and queried the Trove database. Three searches were conducted in early August 2017 using the search criteria as shown in Table 1.

From the initial list of 52 theses retrieved, we checked details of each thesis and determined the academic qualification awarded, year of award, institution, faculty and availability of electronic copy of thesis document. Five Masters theses were eliminated as being outside the scope of this study. One doctoral thesis was excluded because although it included DSR as a keyword, the candidate explicitly stated that its research methodology was not DSR. A further five theses were excluded as they were more closely aligned with engineering or science disciplines rather than information systems.

Four of the Doctoral theses were not available (2 on microfiche, 1 not available, 1 under embargo) and were not included for in-depth analysis. Appendix B provides details of the 41 selected doctoral IS DSR theses, including the candidate name, institution, year conferred and the retrieval search criteria. In this paper, the theses are referenced by their identification number #1 to #41.

Search	Search criteria	Count
A	format <thesis>; content <Australian>; keyword phrase <design science research>	46
B	format <thesis>; content <Australian>; keyword phrase <design science>; subject phrase <information systems>	13
C	format <thesis>; content <Australian>; keyword phrase <design theory>; subject phrase <information systems>	2
Total unique records		52
	Excluded from analysis :	
	- Masters thesis	5
	- Non-DSR thesis	1
	- Non- Information Systems discipline	5
Total theses in the sample		41
	Excluded from full text content analysis: E-copy of thesis not available	4
Theses in full text content analysis sample		37

Table 1 Searches of Trove Database – criteria and number of theses retrieved

Step 3. Develop codebook to assess theses. To analyse the selected theses, we followed the approach taken by (Deng et al. 2017) and drawing on examples from previous research (e.g. Leukel et al. 2014) questions and response options were formulated in a codebook. The codebook is provided in Appendix A.

Step 4: Content analysis of theses. Qualitative content analysis (Schreier 2014) was performed to find answers to the codebook questions. Qualitative content analysis is "a method for systematically describing the meaning of qualitative data [performed] by assigning successive parts of the material to the categories of a coding frame" (Schreier 2014). The codebook was implemented in Microsoft Excel. The third author accessed each full-text document to analyse the theses and code the data, by finding the relevant text within the theses. After completing the first round of coding, the three authors reviewed the data analysis to verify the coding and clarify the ambiguities raised due to use of different terminologies in the theses. Then, the second round of document analysis was performed to ensure the consistency and accuracy of coding.

Step 5: Synthesize extracted data. In this step, frequency tables and graphs were compiled from the Excel data collection sheets. These results of the analysis are presented and were discussed to formulate answers to the research questions and link the findings to prior studies.

4 Results

The next section presents the findings from analysis of the Australian theses identified in this study. The demographic information presented in section 4.1 includes all 41 DSR theses. For the detailed analysis presented in section 4.2 and 4.3 the sample comprises the 37 theses available as full-text.

4.1 Demographics

As shown in Appendix B, the 41 DSR theses selected represent candidates enrolled in 18 Australian universities. The time period of the publications of the theses ranged over 11.5 years from 2006 to August 2017. These DSR theses resulted in the award of 37 PhDs, 2 DITs, and 2 DBAs.

The popularity of DSR for Doctoral theses appears to have grown as shown in Figure 1. Since the first DSR thesis completed in 2006 the number peaked at nine in 2011. There is a possibility that not all 2016 theses have been deposited to Trove. Moreover, the number of theses reported for 2017 does not include the entire year. As part-time candidates are allowed seven years to complete a PhD some of the research projects reported here could have commenced as early as 1999.

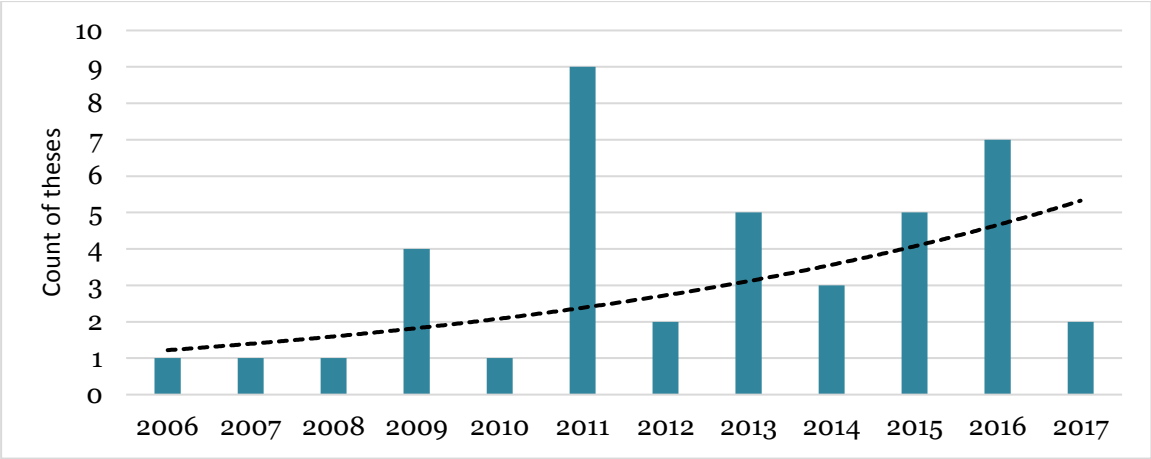

Figure 1. Annual count of completed Australian doctoral DSR theses

Monash University and Queensland University of Technology (QUT), have been the most active IS doctoral research programs with seven and six DSR doctoral graduates respectively (Figure 2). Three universities each published three DSR theses: Australian National University (ANU), University of New South Wales (UNSW), and University of Southern Queensland (USQ). Six universities including James Cook University (JCU), Curtin University, RMIT, University of Melbourne (UniMelb), Murdoch University and University of Canberra (UC) each contributed two doctoral DSR theses. The remaining seven universities that published one DSR thesis each included: University of Wollongong (UoW), Edith Cowan University (ECU), University of Newcastle (UON), University of Queensland (UQ), Griffith University, University of South Australia (UniSA), and University of Tasmania (UTAS).

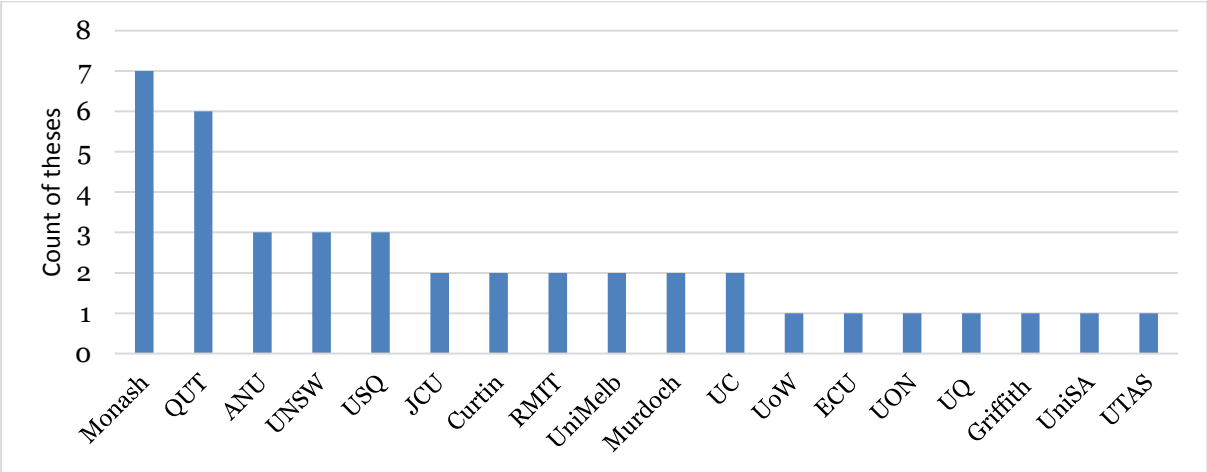

Figure 2. Number of Australian doctoral DSR theses by university

4.2 Outputs - Developed artefacts

The most frequently developed artefact type is method (17), followed by framework (15), instantiation (14), model (11), construct (8) and theory (6).

According to our findings, in 25 out of 37 theses (68%) the artefact did not explicitly lead to new theory or reconsideration of existing theory. New theories were claimed by five candidates (#12; #15; #18; #27; #28), viz. a 'Vision Impaired using Virtual IT Discovery' (VIVID) model (#12), a Framework for the Conceptual Modelling of Knowledge (#15), a Utility theory (#18), design theory for innovation of classroom-based information systems (#27), and initial steps toward a theory of website benchmarking (#28). Changes or extensions to existing theories were reported in seven of the theses (#7; #8; #16; #17; #19; #21; #24). For example thesis #17 extended the theory of technology adoption while thesis #21 provided a real-time extension for Simon's (1977) decision making theory. Thesis #1 claims to test theory, but we were unable to locate a mention of any theories in the manuscript. While these findings can be justified from the pragmatic-camp or complementary approach (Gregor and Hevner 2013), the discrepancy of theoretical contribution is striking if the design-camp becomes the preferred reference DSR approach.

As well as the theoretical contributions mentioned earlier, we considered the number of peer-reviewed academic publications reported by the candidates from their doctoral research. In total, 174 refereed research publications were reported by 37 candidates. The average number of publications per candidate is 4.7 and the range is from a minimum of zero to a maximum of 13. The majority of publications were refereed conference/workshop papers (126); followed by refereed journal papers (41); and seven book chapters.

4.3 Application in the Appropriate Environment

The nature of the research conducted by the candidates is classified as socio-technical (23), technical (13), and organizational (1). Just over half the 37 theses (21) focused on various aspects of the ICT sector (e.g. software engineering, data management/models, service management, mobile computing, medical informatics, social network analytics) while the remainder related to specific industry sectors: Education (5); Health (3); Legal (1); Logistics (1); Research & Innovation (1); Transportation (1); Tourism (1); Organizational Gamification (1) and Engineering/Construction (2). As well as ICT practitioners, such as software developers, enterprise architects, IT service managers, a variety of other industry practitioners and stakeholders are involved in the research including vision impaired learners, patients and medical triage staff, digital forensic practitioners, and logistics professionals.

It is acknowledged that DSR's *raison d'etre* is the development of artefacts that can be applied to the solution of real world problems (Peffers et al. 2007) but for some of the artefacts developed in the doctoral projects, it was not practical to implement them. For instance, in one thesis (#16) the artefact is called "a set of prescriptive statements concerning context-aware IS" and claimed to be a theory artefact. All 37 candidates claimed they had made a contribution to practice. Thirteen candidates stated that they encountered limitations on the number, availability and diversity of participants. As is commonly reported by doctoral candidates, temporal (10) and financial constraints (4) were also mentioned as limitations. For instance, one candidate argued that "for academic research, running an agile software development project involving industrial agile developers and professionals is an expensive kind of trial, and when it is necessary to run multiple iterations, it goes beyond the capacity of a normal doctoral research task. Accordingly, this study was conducted in a simulated agile software development setting in an academic environment with shorter iteration lengths, and therefore does not reflect exact industrial contexts per se" (#25).

5 Discussion

The objective of this work was to understand the types of artefacts created and theoretical contribution, the foundational guidance for building those artefacts, and the evaluation methods applied in DSR as it has been practiced in Australia by doctoral candidates. To achieve this aim details of 41 Australian doctoral theses from graduates during the period 2006 to August 2017 were retrieved. From this sample, content analysis of 37 full-text theses was analysed for evidence. The results from this research provide insights and answers to our two broad research questions.

RQ1. What is the extent of DSR adoption among doctoral candidates in Australia?

The findings indicate that DSR has been widely adopted within Australian IS doctoral programs as at least 41 doctoral candidates in 18 Australian universities have adopted DSR in their doctoral research projects. Also this study found an overall upward trend in the IS doctoral DSR theses. The most active universities in doctoral IS DSR were Monash and QUT.

RQ2. What are the outputs *of Australian doctoral DSR theses?*

We consider academic outputs, artefacts, design theory and contributions to practice reported in the doctoral theses as valid outputs.

It has been postured that publishing DSR results in the best journals is a challenge (e.g. Conboy et al. 2012). Fifteen of the theses contributed a total of 41 journal publications and of these seven were ranked in Quartile 1 (Q1) journals (according to SJR's[1] ranking), nine in Q2 journals, six in Q3 journals and four in Q4 journals. Candidates also reported 126 papers in refereed conference proceedings from their research. Clearly the work is being published although as argued elsewhere (e.g. Conboy et al. 2012) there is little appearing in the very *best* journals. This analysis does not extend to include post-graduation publications. The broader issue of preparedness to publish from doctoral research projects

[1] http://www.scimagojr.com/journalrank.php

has been raised before (Lyytinen et al. 2007). Relatively recently advice on presentation of DSR for publication has been provided (Gregor and Hevner 2013).

The artefact types represented in our sample are consistent with the four previous literature reviews: *method* is most frequent and *construct* the least frequent artefact types. Two additional artefact types reported in the theses were *framework* and *theory*. Similarly, Kotzé et al. (2015) found several theses that reported their developed artefact as a *framework*. One thesis (#16) highlighted the fact that some DSR authors (e.g. Hevner et al. 2004; Kuechler and Vaishnavi 2008) appear to promote the idea that the artefact in IS design science must be a technological artefact (e.g. an IT component or IT representation).

In this study, we found outputs included a broad mixture of artefact types including constructs, models, methods, instantiations, frameworks, and theories. Our categorization of types of artefact was not always straightforward and required the authors to reach consensus during the analysis.

There are conflicting views from leading DSR academics about nomenclature in DSR and as a result broad agreement has not been achieved on terminology, methodology, evaluation criteria, and other aspects (Baskerville 2008; Venable 2010; Venable 2015). Such lack of consensus remains a problem that could affect the outcomes of doctoral studies and cause challenges in the external examination process for doctoral work (where that external process occurs) as well as publication of the work. Of course it is not only DSR that has a problem with standard use of nomenclature in information systems research (Lee 2010).

Theory (new or reconsidered) and in particular design theory is an important output of any DSR research, and no less so for these doctoral projects. However, in more than one-half of the theses the claimed theoretical contributions did not include development of new theory nor extend/re-examine current theory. Of those that claimed a contribution, most pointed to changes to existing theory. Only five asserted they developed new theory. Locating or understanding the contribution made by the majority of these projects by way of 'design theory' was problematic. In some theses, the work of Gregor and Jones (2007) was cited but the design theory components were not clearly articulated.

6 Conclusion

This paper has focused on the adoption DSR in doctoral IS research in Australia. DSR is a relatively new paradigm in IS and its philosophical and methodological foundations are still not thoroughly grounded. Also, the attractiveness of DSR for junior researchers (e.g. HDR candidates) and the position of DSR publications in top IS journals, and integration of DSR with other IS research streams has been questioned by a number of scholars. This paper investigated the use of DSR within doctoral studies in Australia to empirically examine these concerns. The paper sought to show the range of the outputs of doctoral DSR projects and to examine the extent of adoption of DSR by doctoral candidates in Australia.

A content analysis of 41 doctoral theses from 18 Australian universities was used to answer the research questions. The findings showed that DSR is being used by these HDR candidates to address socio-technical, and technical problems in a diverse range of industry settings. It is encouraging to note that candidates have adopted broader and innovative perspectives regarding the types of artefacts created. Those reported in the theses were beyond Hevner et al.'s (2004) list of four artefact types, and include frameworks and theories and key terminologies (e.g. artefact, model, design theory, case study) were used inconsistently. The candidates were able to publish their work in a large number of refereed outlets during their candidature.

6.1 Implications and recommendations

Based on our analysis and the discussion of results, we provide the following lessons learned as recommendations and advice to HDR candidates, their supervisors and DSR scholars' community:

Our analysis of the doctoral theses showed lack of understanding or possibly a misunderstanding of DSR terminologies among the HDR candidates. Considering the relative youth of design science, particularly in IS research, we argue that it is not as established as social science research methods and there is still debate on some fundamentals of DSR among leading scholars in this field. Hence, we strongly recommend candidates to conduct a thorough review of DSR literature as a prerequisite to beginning their DSR project to obtain mastery of DSR knowledge and be aware of the different views in the field. Furthermore, we believe that formal training in DSR is needed for HDR students as well as supervisors to overcome the current gap in DSR knowledge utilization. Particularly for Australian doctoral programs that normally do not require coursework, a formal DSR training for IS/IT doctoral students is highly recommended. Examples of such formal training can be found in American (Vaishnavi and Kuechler

2015) and European universities e.g. IT University of Copenhagen (ITUC 2016) and Technical University of Munich (TUM 2016).

We echo previous recommendations (e.g. Venable 2010; Venable 2015; Winter 2008) and encourage leading DSR scholars to work towards establishing commonly accepted research foundations for DSR in IS. In particular, clearly defined terminology supported by adequate examples of what is meant by any specific term (e.g. artefact, model, framework) and what is not meant, are necessary for improvement of DSR discipline. The current body of DSR literature was found not only ambiguous and difficult to understand by HDR students but also made it difficult for us to analyse the data since different candidates have used the terms (e.g. model, method, and framework) inconsistently.

Since significant DSR usually involves many researchers over several years (Gregor and Hevner 2013), HDR candidates should be mindful in defining the scope of their doctoral project. A wide project scope may prevent the researcher from adequately following DSR guidelines.

6.2 Limitations

As with any research work, we recognize limitations in terms of the method used. The scope of the review of DSR studies is limited to 41 doctoral theses from 18 Australian universities. Within this sample, while Trove is the commonly used repository of HDR theses completed in Australia, it cannot be claimed that all HDR theses are submitted to Trove. In addition, our search criteria may have failed to select some theses from the repository. In terms of the outputs from the theses, we relied solely on the publications mentioned within the theses. A more extensive project could consider the quantity and quality of publications by candidates subsequent to their graduation.

6.3 Future research

We encourage researchers in other geographic areas to consider how DSR research is conducted by HDR students in their regions. This would enable future comparisons to identify specific factors that could be addressed on a local or global scale. Particularly, comparison of the rigor of US or European DSR theses with the rigor of Australian theses can shed light on the effect of formal training on the quality of DSR work.

In this paper, we focussed on the outputs of Australian doctoral DSR research. A topic for future research concerns the experience of doctoral candidates in applying DSR in their doctoral research projects. For example, future studies could explore the research processes that were employed by doctoral candidates, the complexity of DSR, lack of clarification of fundamental concepts, unsettled debates, lack of formal training, and limited time of a doctoral study or the preferences of supervisors.

In light of the emergence of methodological contributions to design science, we are optimistic that DSR will continue to be an attractive approach for research students. The provision of effective resources and training will enable the next generation of DSR scholars to create artefacts valued in the appropriate environment and to make theoretically strong contributions to the IS research knowledge base.

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Appendix A Analysis Code-book: Questions and Response Options

1. Thesis Title:
2. Author:
3. Year:
4. University:
5. School/Department
6. What artefact was designed?
   a) Construct b) Model c) Method d) Instantiation e) Theory/Framework
7. Nature of research?
   a) Technical b) Socio-Technical c) Organizational
8. Targeted sector/industry?
9. Number of peer-reviewed publications?
   a) Journal papers: b) Refereed conference/ workshop papers: c) Book chapters:
10. Limitations/challenges of applying DSR in the doctoral thesis

Appendix B Australian Doctoral DSR Theses Retrieved for Analysis

#	Candidate	Year	University	Search criteria	#	Candidate	Year	University	Search criteria
1	Matus-Castillejos, A.	2006	UC	A	22	Wong, A. K. L.	2014	Monash	A
2	Nyaga, C. K.	2007	ECU	A	23	Grigsby, S. A.	2011	Monash	A
3	Valverde, R.	2008	USQ	B	24	Cheung, R. C. T.	2013	UniSA	A
4	Ducrou, A. J.	2009	UoW	A	25	Adikari, S.	2014	UoC	A
5	La Rosa, M.	2009	QUT	A,B	26	Feris, M.	2015	ANU	A
6	Redding, G. M.	2009	QUT	B	27	Hellmuth, W. J.	2015	QUT	A
7	Pearson, N.H.	2010	QUT	A.B	28	Cassidy, L. J.	2015	JCU	A
8	Xie, J	2011	Monash	A	29	Shrestha, A.	2015	USQ	A
9	Fung, K. H.	2011	UNSW	A	30	Raphiphan, P.	2015	Monash	A
10	Jones, D. T.	2011	ANU	C	31	Raftopoulos, M	2016	RMIT	B
11	Adams, R.	2011	Murdoch	A	32	Rehn, A. J.	2016	JCU	A
12	Permvattana, R.	2011	Curtin	A	33	Jafarov, N.	2016	UNSW	A
13	Finney, K.T.	2011	UTAS	A	34	Yesudas, R.	2016	ANU	A
14	Omar, M. F.	2012	QUT	A	35	Amirebrahimi, S.	2016	UniMelb	A,B
15	Pigott, D.	2012	Murdoch	A	36	Khademi Habibabadi, S.	2016	Monash	A
16	Ploesser, K.	2013	QUT	A,B,C	37	Laylavi, F.	2017	UniMelb	A
17	Md Ali, A.	2013	RMIT	A	38*	Shih, S.	2016	UON	A
18	Meersman, D.	2013	Curtin	A	39*	Amrollahi, A	2017	Griffith	A
19	Gacenga, F. N.	2013	USQ	A	40*	Nantiyakul, N.	2009	Monash	B
20	Esmaeil Zadeh, M.	2011	UNSW	A,B	41*	Gibson, M. C.	2011	Monash	A, B
21	Gao, S-J	2014	UQ	A					

* Full-text of thesis not available from Institution