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RESEARCH PERSPECTIVE

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Design Science Research in Doctoral Projects: An Analysis of Australian Theses

Aileen Cater-Steel[1], Mark Toleman[2], Mohammad Mehdi Rajaeian[3]

[1]University of Southern Queensland, Australia, Aileen.Cater-Steel@usq.edu.au
[2]University of Southern Queensland, Australia, Mark.Toleman@usq.edu.au
[3] Australian Catholic University, Australia, MohammadMehdi.Rajaeian@acu.edu.au

Abstract

Design science research (DSR) has gained popularity with doctoral students. In the information systems (IS) discipline, DSR is distinctive in that it creates knowledge through the design of novel or innovative artifacts and analyzes the artifacts' use or performance. We present an analysis of 40 DSR doctoral theses completed in Australia between 2006-2017. Our purpose is to understand how DSR is applied by the IS community, and one critical source of information is the work of doctoral candidates. How candidates are guided by the literature, the artifacts produced, and their evaluation of the artifacts provide a window into this understanding. We selected the theses from the Australian national repository and analyzed their content. The findings suggest: (1) DSR is evolving and maturing in this cohort, but most candidates fail to enunciate and understand the underlying philosophy of their research approach; (2) the use of relevant guidance is still developing; and (3) the capacity of candidates to theorize about their work remains a challenge, possibly due to problems of scoping DSR projects and ensuing time constraints. In spite of their recognition and appreciation of the need for evaluating DSR artifacts, it is questionable whether doctoral candidates understand that the designs also require evaluation. As in many other areas of IS research, nomenclature in DSR remains problematic and the whole IS community should aim to create better consistency in this regard. This paper contributes toward our understanding of the challenges and advantages of DSR as a research approach for postgraduate studies and offers recommendations to the DSR community.

Keywords: Design Science Research, Doctoral Research, Research Methods, Evaluation.

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1 Introduction

Design science research (DSR) is recognized as an important and legitimate information systems (IS) research paradigm (Gregor & Hevner, 2013). DSR is essential for information systems research because a considerable subset of IS research is focused on designing artifacts. Furthermore, DSR has been promoted as an approach to improving the rigor and relevance of IS research (Hevner, March, Park, & Ram, 2004). A recent review of papers in seven major IS journals revealed that although DSR had been one of the approaches "receiving the least traction" in IS, it has shown "phenomenal" emergence from 2004-2013 (Deng & Ji, 2018; Palvia, Kakhki, Ghoshal, Uppala, & Wang, 2015, p. 639).

Despite widespread recognition, DSR has not yet attained its full potential impact because of "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 & Hevner, 2013, pp. 337-338).

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, van der Merwe, & Gerber, 2015). However, concerns have been raised that DSR may not be an attractive paradigm for junior researchers (Österle et al., 2011) and that junior researchers might be advised to avoid DSR if it requires theory development and testing, rigorous artifact design, demonstration and evaluation (Peffers, Tuunanen, & Niehaves, 2018). One possible reason for students' reluctance to use DSR may be the time limitation since "a significant DSR program typically encompasses many researchers over several years" (Gregor & Hevner, 2013, p. 339).

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 the knowledge and expertise needed to acquire gainful employment in the industry (Gill & 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, Galliers, & Whitley, 2016). For instance, in spite of the limited number of DSR studies in top IS journals (Palvia et al., 2015), an 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% in 2003 to 25% in 2012 (Stein et al., 2016).

Although various researchers have analyzed the publication of DSR journal papers (Amrollahi, Ghapanchi, & Talaei-Khoei, 2014; Arnott & Pervan, 2012, 2014; Deng & Ji, 2018; Leukel, Mueller, & Sugumaran, 2014) and conference papers (Indulska & Recker, 2008), to date little attention has been paid to the work undertaken by doctoral 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 doctoral students who have adopted DSR is still not well documented (Kotzé et al., 2015) and the feedback for improvement of DSR theory and DSR guidelines is lacking. To address this gap, we seek to answer the following research questions:

RQ1: What DSR literature is cited by Australian doctoral candidates and how is guidance from the literature applied?

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, specifically in the context of doctoral student research. To achieve this objective, we undertake a comprehensive document analysis of DSR doctoral theses and apply content analysis to extract key characteristics.

Australian IS researchers have shown significant interest in DSR. According to research conducted by Indulska and Recker (2008), Australia was the third 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 offer insights for the wider IS research community. In addition, our work provides a basis for future studies comparing the use of DSR in different geographical locations.

This paper is divided into six sections. In the next section, we summarize prior research on the review and assessment of DSR publications (papers and theses) and synthesize DSR reference literature in order to establish a basis to analyze DSR theses and identify their key characteristics. This is followed by a description of the approach we took to analyze Australian doctoral theses. In Section 4, we present the results of the analysis. Finally, in the discussion section, we answer the research questions and raise key issues, following this with recommendations for doctoral candidates and their supervisors. The conclusion provides a summary, limitations of our research, and an agenda for future work.

2 Theoretical Background

2.1 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 artifact development aimed to solve soft business problems (e.g., making IT investment decisions), technology problems (e.g., algorithms) and system development problems. Indulska and Recker (2008) reviewed 83 papers published in five top AIS-sponsored IS conferences in the years 2005-2007 and identified process modeling and 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 Business & Information

Systems Engineering (BISE) researchers in 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 & Pervan, 2014). Arnott and Pervan (2012) employed Hevner et al.'s (2004) seven guidelines to assess the use of DSR in DSS research. Their assessment of 362 DSS design-science research papers published between 1990-2005 in 14 journals revealed major issues in the DSR-based DSS literature, i.e., research design, evaluation, relevance, strategic focus, and theorizing. The distribution of the developed artifacts was construct 0.5%, model 7.1%, method 26%, and instantiation 66.4%. 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% of the papers had a strategic focus. They also found that "only a surprisingly small 2.4% of DSS design-science projects have made contributions to the theory focused areas of design foundations and methodologies" (Arnott & Pervan, 2012, p. 941).

These reviews of published DSR papers have raised concerns related to the rigor of DSR studies and they called for further work on theoretical and methodological underpinnings: for example, DSR theoretical foundations of artifacts have not been well-articulated, use of terminology is inconsistent, and there is poor conformance to DSR guidelines for artifact types and evaluation (Arnott & Pervan, 2012; Indulska & Recker, 2008; Leukel et al., 2014).

2.2 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 artifacts produced, the research designs followed, the motivation for selecting DSR and the students' experience in using DSR. The developed artifacts 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 artifacts to be limited in terms of artifact categorization, and thus added the *framework* type. Kotzé et al. (2015) also identified the cyclical nature and the relevance aspects when developing artifacts as the strengths of DSR theses, but found the philosophical underpinnings to be weak.

In the second study, Venter, de la Harpe, Ponelis, and Renaud (2015) presented the findings from their assessment of two theses that used DSR (one master's thesis in information systems and one doctoral thesis in computer science) conducted at two South African 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. Venter et al. (2015) echoed Winter's (2008) call for a consistent DSR approach and the need for DSR guidelines that support students and supervisors.

2.3 Elements of Design Science Research

While many scholars over the past decades have contributed to design science research in information systems, it was the paper by Hevner et al. (2004) that gave momentum to DSR in IS, and some scholars recognize it as a "de facto standard for the conduct and evaluation of design science research" (Venable, 2010, p. 109). In contrasting the two main paradigms used in information systems research, Hevner et al. (2004) explained that design science "seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts," while behavioral science "seeks to develop and verify theories that explain or predict human or organizational behavior." The information systems research (ISR) framework (Hevner et al. 2004) shown in Figure 1 illustrates the main building blocks of DSR and can be used as an overarching framework to conduct DSR or to identify essential characteristics of DSR studies (e.g., Leukel et al., 2014).

In the next sections we draw on DSR to elaborate on the three elements that comprise the ISR framework: environment (people, organizations, and technology); knowledge base (foundations and methodologies); and IS research (develop/build, justify/evaluate).

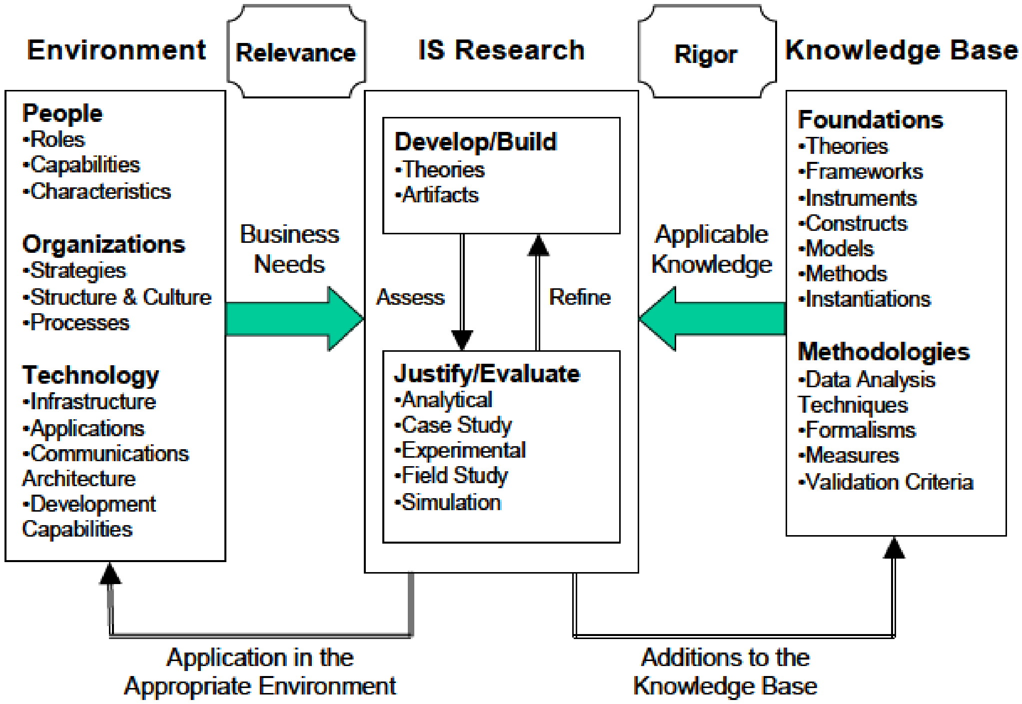

Figure 1. Information Systems Research Framework (Hevner et al., 2004)

2.3.1 Environment: People, Organizations, and Technology

The environment defines the problem space within which the phenomena of interest exist (Hevner et al., 2004; Simon, 1996). The objective of DSR is to develop technology-based solutions to important and relevant business problems (Hevner et al., 2004). Understanding the environment in which the artifact operates is essential in DSR because artifact performance is related to that environment. Limited understanding of that environment can result in "inappropriately designed artifacts or artifacts that result in undesirable side-effects" (March & Smith, 1995, p. 254).

As highlighted by Hevner et al. (2004), IS research is both an organizational and a technical discipline that is concerned with the analysis, construction, deployment, use, evaluation, evolution, and management of information systems artifacts in organizational settings (Madnick, 1992; Orlikowski & Barley, 2001). Nevertheless, Hevner et al.'s definition of IT artifact does not consider nontechnical artifacts as legitimate artifacts in IS research. Hevner et al. (2004) wrote: "we do not include people or elements of organizations in our definition nor do we explicitly include the process by which such artifacts evolve over time" (p.82). Rather than purely technical artifacts, Alter's (2013) "work system theory" advocates a sociotechnical view of artifacts within IS. Orlikowski and Iacono (2001) also advocated the relevance of sociotechnical artifacts to IS; however, they argued for an *ensemble* view of artifacts in which the IT artifact is present and the focus is on the dynamic interaction between people and technology. Orlikowski and Iacono (2001) identified the absence of IT artifacts (i.e., the technical artifacts) in IS research and artifacts that rely solely on "black-boxed [IT artifacts], abstracted from social life, or reduced to surrogate measures" (p. 130) as important challenges for the IS discipline.

2.3.2 Knowledge Base: Foundations and Methodologies

The knowledge base is comprised of foundations and methodologies. Foundational theories are derived from prior research and result from reference disciplines, frameworks, instruments, constructs, models, methods, and instantiations used in the develop/build phase of a DSR study.

Theories from natural or social science, called *kernel theories* by Walls, Widmeyer, and El Sawy (1992) and *justificatory knowledge* by Gregor and Jones (2007), govern the *design requirements* and the *design process.* Such knowledge is used to articulate design principles to "define the structure, organization, and functioning of the design product or design method" (Gregor & Jones, 2007, p. 325).

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 &

Pervan, 2012, p. 924). 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 the emphasis on design theory as a product of DSR. Gregor and Hevner (2013) identified a *design-theory camp* (e.g., Gregor & Jones, 2007; Walls et al., 1992; Walls, Widmeyer, & El Sawy, 2004), and a *pragmatic-design camp* (e.g., Hevner et al., 2004; March & Smith, 1995) with the two camps placing comparatively more emphasis on design theory or artifacts, respectively, as research contributions. Further, Gregor and Hevner (2013) suggest 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).

Methodologies provide guidelines used in the justify/evaluate phase (Hevner et al., 2004). In terms of research philosophy, Iivari (2007) applied the notions of ontology, epistemology, methodology, and ethics to DSR. He expressed the need for constructive research methods in DSR. Different opinions have been presented on how to categorize DSR. For example, DSR has been viewed as a *paradigm* by some researchers (e.g., Gregor & Jones, 2007; Hevner, 2007; Hevner et al., 2004; Iivari, 2007) and a *methodology* by others (e.g., Palvia et al., 2015). Consistent with leading DSR scholars, we hold the view that DSR is a paradigm and that the performance of DSR is supported by various methodologies such as DSR in Information Systems (e.g., Baskerville, Pries-Heje, & Venable, 2009; Kuechler & Vaishnavi, 2008; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).

2.3.3 IS Research: Develop/Build and Justify/Evaluate

To guide the process of development and evaluation of artifacts and (design) theories, several guidelines have been suggested. Among them, the seven guidelines presented in Hevner et al. (2004) have received broad attention: (1) design as an artifact, (2) problem relevance, (3) design evaluation, (4) research contributions, (5) research rigor, (6) design as a search, and (7) communication of design-science research.

Four types of artifacts were proposed by March and Smith (1995): 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 artifact in its environment which operationalizes constructs, models, and methods). More recently, theorizing has been seen as an important DSR output (Gregor & Jones, 2007) and *theory* has been included as a possible DSR artifact (Winter, 2008). Peffers, Rothenberger, Tuunanen, and Vaezi (2012) developed a taxonomy of artifact types by reviewing 148 design science papers in information systems and computer science. Their taxonomy includes *framework* (described as metamodel) and *algorithm*, in addition to the four artifact types proposed by March and Smith (1995), whereas Gregor (2006) considers frameworks as a type of theory.

The analysis of DSR papers in IS journals by Amrollahi et al. (2014) found the most frequently reported artifact type was method (49%), followed by model (24%), IT artifact (15%), and, finally, theory (12%). This distribution is reasonably consistent with the findings from the review of BISE journals and conferences conducted by Leukel et al. (2014): method (59%), model (25%), instantiation (10%), and construct (6%).

Hevner et al. (2004) provided a taxonomy of evaluation methods for DSR. Their taxonomy classifies 12 evaluation methods under five categories: observational (case study, field study); analytical (static analysis, architecture analysis, optimization, dynamic testing); experimental (controlled experiment, simulation); testing (functional, structural); and descriptive (informed argument, scenarios).

The DSR Evaluation Method Selection Framework (Venable, Pries-Heje, & Baskerville, 2012) provides another perspective on the evaluation methods. The framework provides classification of evaluation methods along two dimensions. The first dimension considers the timing of conducting evaluation. Evaluation prior to artifact construction is called *ex ante* or *formative* evaluation and evaluation after artifact construction is named *ex post* or *summative* evaluation. The second dimension classifies the evaluation methods as naturalistic (e.g., field setting) versus artificial (e.g., laboratory setting). Recently, Venable, Pries-Heje, and Baskerville (2016) proposed a framework and guidelines that consider *why*, *when*, *how*, and *what* to evaluate for evaluation of artifacts developed within a DSR project.

The DSR knowledge contribution framework proposed by Gregor and Hevner (2013) comprises two dimensions: application domain maturity and solution maturity. These dimensions form four quadrants: invention, improvement, exaptation, and routine design. This proposed framework may be useful for researchers to justify DSR outcomes and to demonstrate knowledge contributions. Previous research has raised the issue that DSR authors face challenges in communicating new ideas to the stakeholder communities and achieving publication in journals (Gregor & Hevner, 2013). To address issues on the presentation of DSR theses and papers, Gregor and Hevner (2013) provided advice using an example of a DSR study.

In summary, our review of relevant literature raised concerns about the quality of DSR studies and limited conformance to DSR guidelines, in general, and in doctoral studies, in particular. We also noted limited prior research on the use of DSR by doctoral students. We identified the ISR framework (Figure 1) to be an appropriate framework to specify elements of DSR studies and gave examples of DSR related to the three elements that comprise the ISR framework: environment (people, organizations and technology); knowledge base (foundations and methodologies), and IS research (develop/build, justify/evaluate). In the next section we elaborate on our use of this framework to underpin our analysis of the DSR studies.

3 Method

The method to analyze Australian doctoral DSR theses comprised five steps: (1) identify resources, (2) select DSR theses, (3) develop codebook to assess theses, (4) extract data from theses, and (5) synthesize extracted data. These steps were adapted from advice on conducting systematic literature reviews (Kitchenham & Charters, 2007).

Step 1. Identify Resources. All Australian universities are required to maintain a digital repository for 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 as open access via the institutions' library websites, and links are recorded in Trove, the National Library of Australia's online repository (see http://trove.nla.gov.au/).

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

Table 1. Searches of Trove Database: Criteria and Number of Theses Retrieved

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:		
- Master's theses		6
- Non-DSR theses		1
- Non-information systems discipline thesis		5
Total theses identified through Trove and selected for full-text content analysis		**40**

From the initial list of 52 theses retrieved, we reviewed details of each thesis and determined the academic qualification awarded, year of award, institution, and faculty. Six master's 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 approach was not DSR. A further five theses were excluded as they were more closely aligned with engineering or science disciplines rather than information systems. Appendix B provides details of the 40 selected doctoral IS DSR theses, including the candidate name, thesis title, institution, year conferred and the retrieval search criteria. In this paper, the theses are referenced by their identification number #1 to #40 and identified in Appendix B. All the selected theses used a DSR approach to solve a problem.

Step 3. Develop codebook to assess theses. To analyze the selected theses, we followed the approach taken by Leukel et al. (2014) and applied the ISR framework (Hevner et al., 2004) presented above in Figure 1.

Based on Hevner et al.'s ISR framework and our review of DSR literature (Section 2.3) and drawing on examples from previous research (e.g., Leukel et al., 2014), questions and response options were formulated in a codebook. The codebook format is provided in Appendix A. Two authors pretested the use of the codebook by independently analyzing two theses and discussing the results to achieve consensus and improve the questions and response options.

Step 4. Content analysis of theses. We performed qualitative content analysis (Schreier, 2014) 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 NVivo software, by defining each question as a node and each response option as a subnode (Bazeley & Jackson, 2013). The third author accessed each full-text document to analyze the theses and code the data by finding the relevant text within the theses and assigning text fragments to response subnodes. Response options for Question 8 (DSR literature) and Question 9 (DSR guidelines) emerged from the first round of document analysis. Each question in the codebook allowed an "other" category distinct from the response options offered to be recorded. Using NVivo made a reliable document analysis possible by recording the exact location of the text used to answer the questions in the codebook (Boréus & Bergström, 2017). Also, NVivo facilitated document analysis by providing the search capability across multiple documents.

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 different terminologies used in the theses. Then, the second round of document analysis was performed to ensure the consistency and accuracy of coding. Due to the emergent nature of response options for Question 8 and Question 9, we conducted searches for each emergent response (i.e., citation of DSR article) across all theses to ensure the accuracy of citation analysis.

Step 5. Synthesize extracted data. We transferred the NVivo output to Excel and compiled frequency tables and graphs based on the Excel data collection sheets. In the following section, we present the results of the analysis and discuss them in order to formulate answers to the research questions and link the findings to prior studies.

4 Results

The next section summarizes the demographics of the theses and then presents the findings structured according to the three relevance and rigor elements ISR framework (Figure 1): environment (people, organizations and technology); knowledge base (foundations and methodologies); and IS research (develop/build, justify/evaluate). We then present findings derived from additions to the knowledge base and application in the appropriate environment.

4.1 Demographics

As shown in Appendix B, the 40 DSR theses selected represent candidates enrolled in 19 Australian universities. The time period of the finalization of the theses ranged over 12 years from 2006-2017.

The popularity of DSR for doctoral theses appears to have grown. Since the first DSR thesis (in our study) completed in 2006, the number peaked at six in 2015 and 2016. There is a possibility that not all the recently completed theses were submitted to Trove. As part-time candidates are allowed seven years to complete a PhD, some of the research projects reported here may have commenced as early as 1999.

4.2 Environment: People, Organizations, and Technology

The nature of the research conducted by the candidates is classified as sociotechnical (28) and technical (12). Just over half the theses (17) focused on various aspects of the ICT sector (e.g., software development, data management/models, service management, architecture) 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 construction (2). In addition to ICT practitioners, such as software developers, enterprise architects, and IT service managers, a variety of other industry practitioners and stakeholders were involved in the research including vision-impaired learners, medical patients and medical triage staff, digital forensic practitioners, and logistics professionals. The geographical location and scope were not articulated (or applicable) in 21 of the theses. The remaining 19 theses defined the scope broadly as within Australia (15), Thailand (2), Malaysia (1) or multiple countries (1).

4.3 Knowledge Base: Foundations and Methodologies

In terms of foundations, the first characteristic we considered was the research philosophy. As shown in Figure 2, 18 theses did not include any discussion about the underpinning philosophy of their research (e.g., ontology, epistemology, or axiology). Six theses had very limited discussion about their philosophical view and considered DSR as a stand-alone research paradigm. Having discussed the debate on philosophical views in DSR, #17 did not take a position in favor of any of the views and did not adopt an explicit research philosophy: "Regardless of whether Design Science is classed as a 'paradigm', a 'body of knowledge' or a 'type of research method', it was used as a guiding framework and employed in this thesis to develop a prototype, semantically-grounded Feature Catalogue" (#17). Interestingly Thesis #17 also portrays DSR as an alternative to qualitative and quantitative paradigms.

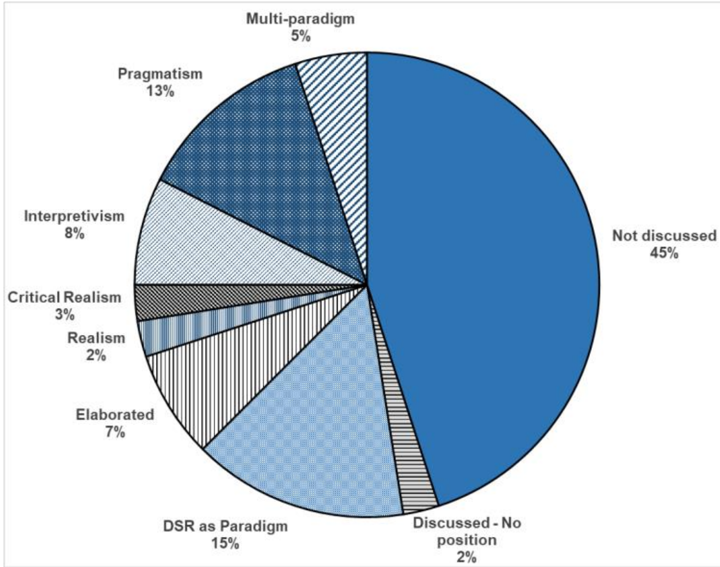

Figure 2. Distribution of Research Philosophies in DSR Theses

Of the 15 candidates who stated their research philosophy, five adopted pragmatism (#7, #12, #14, #24, #26); three interpretivism (#10, #21, #39); one realism (#23); one critical realism (#30); and two multiparadigm philosophies (#2: pragmatism & social constructionism; #37: pragmatism & interpretivism). Three others elaborated their ontological and epistemological views as follows: objective ontology, sociotechnologist/developmentalist epistemology (#1); ontology as a single, stable (physical) reality underlying multiple possible world states, and epistemology as knowing through making theory-ingrained artefacts (#20); ontology as multiple realities, and epistemology as objective and subjective (#32).

In terms of methodology, there is confusion about whether DSR is a paradigm or a methodology, which was reflected by 34 of the 40 candidates referring to DSR as their *research methodology*, consistent with the terminology of some design science researchers (e.g., Palvia et al., 2015). This is in contradiction to the view of most DSR scholars (e.g., Baskerville, 2008; Iivari, 2007) who consider DSR to be *research paradigm*. Surveys were used most often in the methodologies (in 10 theses) for evaluation purposes (#13, #24, #26, #28, #31, #34) and for problem analysis/formulation (#8, #17, #23, #37). Focus groups were used in nine theses for evaluation (#4, #8, #14, #15, #17, #24, #28) or for artifact development (#22; #29). Action research was used in five theses for the design, development, and evaluation of the studies' artifacts (#8, #12, #19, #22, #28). In one thesis (#12), DSR was named as the paradigm and action research as the research method. Similarly, in another thesis (#22) a hybrid methodology of action research and DSR was used; the DSR approach was employed to build the IS artifact and action research provided a guiding framework to select and interact with the industry domains. A grounded-theory approach was used in two theses (#37; #39) for theory building.

Design principles were mentioned in 17 of the theses and explicitly followed by 11 candidates (#10; #12; #15; #16 #19; #24; #26; #28; #30, #34, #36). Although all theses used theories or frameworks from the knowledge base, only seven theses explicated those theories as their *kernel* theories (#7; #12; #19; #20; #28; #30, #39).

In total, 48 research papers were referenced by candidates for DSR guidance or to justify their DSR approach/method. Appendix C lists all the cited literature and provides details of the frequencies of references to these publications. All candidates referred to the work of Hevner et al. (2004) and the majority of theses (29) also mention March and Smith (1995). In terms of applying DSR guidelines in the research, while 33 candidates claimed to have followed a guideline or a combination of guidelines, seven candidates made no mention of specific DSR guidelines. The work of Hevner et al. (2004) was the most frequently cited guideline and was used as guidance in 13 theses. Eight theses followed Peffers et al. (2007) while three referred to Venable (2006).

The frequency of use of DSR guidelines followed by the candidates is shown in Figure 3. In total, 13 of the candidates claimed to have followed the seven-step guidelines promoted by Hevner et al. (2004) to evaluate design. As shown in Table 2, eleven of these candidates explicitly discussed the realization of each of the guidelines in their thesis. The remaining two did not show how all the guidelines were applied, but there is evidence that some of the guidelines were followed.

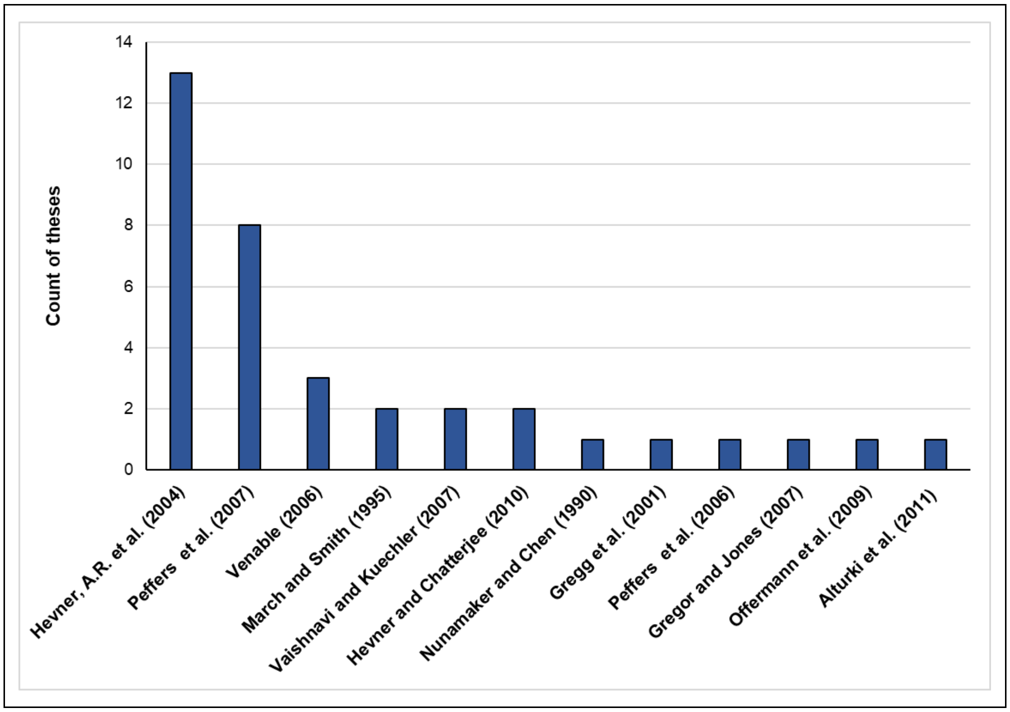

Figure 3. Frequency of Use of Specific DSR Published Guidelines

Table 2. Candidates' Self-assessment of Conformance to Seven Guidelines (Hevner et al. 2004)

Guidelines from Hevner et al. (2004)	**Thesis #**													
	#2	**#6**	**#7**	**#9**	**#10**	**#13**	**#14**	**#17**	**#26**	**#33**	**#34**	**#36**	**#37**	**Count**
1: Design as an artifact	X	X	X	X	X	X	X	X	X	X	X	X	X	**13**
2: Problem relevance	X	X	X	X	X	X	X	X	X	X	X	X	X	**13**
3: Design evaluation	X	X	X	X	X	X	X	X	X	X	X	X	X	**13**
4: Research contributions	X	X	X	X	X	X	X	X	X	X	X	X	X	**13**
5: Research rigor	X		X	X	X	X	X	X	X	X	X	X	X	**12**
6: Design as a search	X		X	X	X	X	X	X	X	X	X	X		**11**
7: Communication of design-science research	X		X	X	X	X	X	X	X	X	X	X	X	**12**
Total number of guidelines	**7**	**4**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**6**	

4.4 IS Research: Develop/Build and Justify/Evaluate

Sixty percent of the candidates (24) focused their work on the development of a single artifact. Two artifacts were developed by 10 candidates, four reported the development of three artifacts, and a further two candidates claimed to have developed four artifacts. The most frequently developed artifact type is method (16), followed by framework (15), instantiation (13), model (8), construct (7), and theory (5).

According to our findings, in 60% of the theses (24) the artifact did not explicitly lead to new theory or reconsideration of existing theory. Five candidates claimed they developed new theories (#16; #19; #21; #28; #29)—i.e., a vision-impaired model using virtual IT discovery (VIVID) (#16), a framework for the conceptual modeling of knowledge (#19), a utility theory (#21), design theory for innovation of classroom-based information systems (#28), and initial steps toward a theory of website benchmarking (#29). Changes or extensions to existing theories were reported in seven of the theses (#7; #8; #9; #10; #20; #23; #24). For example, thesis #24 extended the theory of technology adoption, while thesis #9 provided a real-time extension for Simon's (1977) decision-making theory. Thesis #1 claims that it tests theory, but we were unable to locate a mention of any theories in the manuscript. Evaluation of the designed artifact is an important activity and the candidates selected various evaluation methods as listed in Table 3. Case studies (17) and expert evaluation (16) were the most frequently used evaluation methods.

A different perspective on candidates' choice of evaluation methods is provided by mapping the evaluations according to the DSR evaluation method selection framework that classifies evaluation methods according to the timing and setting of the evaluation (Venable et al., 2012). Although all four dimensions are represented, the evaluation activity is highest in the Ex post naturalistic quadrant. Table 4 presents the frequency of evaluation methods used according to the DSR evaluation method-selection framework.

In addition to the theoretical contributions mentioned above, we considered the number of peer-reviewed academic publications reported by the candidates in their doctoral research. In total, 188 refereed research publications were reported by candidates. The average number of publications per candidate was 4.7, ranging from a minimum of zero to a maximum of 13. The majority of publications were refereed conference/workshop papers (138), followed by refereed journal papers (41), and book chapters (9).

Table 3. Evaluation Methods Based on Categories Defined by Hevner et al. (2004) and Peffers et al. (2012)

Category of Evaluation Method	Evaluation Method	Definition	Count
Observational	Case Study	Study artifact in depth in business environment	**17**
	Field Study	Monitor use of artifact in multiple projects	**5**
Analytical	Static Analysis	Examine structure of artifact for static qualities	**3**
	Architecture Analysis	Study fit of artifact into technical IS architecture	**2**
	Optimization	Demonstrate optimality bounds on artifact behavior	**0**
	Dynamic Testing	Study artifact in use for dynamic qualities	**0**
Experimental	Controlled experiment	Study artifact in controlled environment for qualities	**5**
	Simulation	Execute artifact with artificial data	**4**
	Expert evaluation	Assessment of an artifact by one or more experts	**16**
Testing	Functional (black box)	Execute artifact interfaces to discover failures and identify defects	**4**
	Structural (white box)	Perform coverage testing of some metric in the artifact implementation	**2**
Descriptive	Informed argument	Use information from the knowledge base to build a convincing argument for the artifact's utility	**7**
	Scenarios	Construct detailed scenarios around the artifact to demonstrate its utility	**1**

Table 4. DSR Evaluation Method Selection Framework (Adapted from Venable et al., 2016)

	Ex ante: formative	Ex post: summative
Naturalistic	Action research (6)	Action research (6) Case study (17) Field study (5) Expert evaluation (survey/focus group) (16)
Artificial	Criteria-based evaluation / informed argument (7) Static analysis (3) Architectural analysis (2) Structural testing (1)	Controlled (lab) experiment (5) Functional testing (4) Structural testing (2) Computer simulation (4) Scenarios (1)

4.5 Application in the Appropriate Environment

It is acknowledged that DSR's raison d'etre is the development of artifacts that can be applied to the solution of real-world problems (Peffers et al., 2007) but for some of the artifacts developed in the doctoral projects, it was not practical to implement them. For instance, in one thesis (#20) the artifact is called "a set of prescriptive statements concerning context-aware IS" and claimed to be a theory artifact. All 40 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 (in 9 theses) and financial constraints (in 3 theses) 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 aim of this research was to examine the design science research of Australian doctoral candidates to gain an understanding of the types of DSR artifacts created, the theoretical contributions made, the foundational guidance used to build the artifacts, and the DSR evaluation methods applied in these projects. To this end, we examined evidence presented in 40 Australian doctoral theses during the period 2006-2017. The results from this research provide insights and answers to our two broad research questions.

RQ1: What DSR literature is cited by Australian doctoral candidates and how is guidance from the literature applied?

While all theses cited Hevner et al. (2004) only 13 candidates actually used some or all of the methodological guidelines. Some candidates may have found it difficult to use the guidelines. Arnott and Pervan (2012), for example, invoke a lack of guidance on how to define and assess problem relevance (Guideline #2). Graduates of information systems programs or business schools in our study tended to place more emphasis on the use of a methodology in this context than graduates from information technology or computer science programs. That is, Information Systems graduates seemed more aware of the value of and need to formally explicate an underlying design methodology. This finding on the use of guidelines is consistent with that of Indulska and Recker (2008), whose conclusion that guidelines still require operationalizing and instantiation before they will be more widely adopted continues to be relevant.

The vast majority of candidates considered DSR as a *methodology* rather than a *paradigm*. The debate about the paradigmatic status of design science research was presented in only one of the theses (#17). While some scholars (e.g., Baskerville, 2008; Hevner et al., 2004; Iivari, 2007; Vaishnavi & Kuechler, 2015) have argued that design science is a paradigm in its own right since the design science ontology, epistemology, and axiology cannot be derived from any other existing paradigm, other authors contend that design science is a "body of knowledge" (McKay & Marshall, 2005) or a "type of research method" (Gregory, 2011). In general, we identified a lack of understanding and enunciation of underlying research philosophies in the theses; less than one half of the theses discussed this aspect, while some relied on simply mentioning DSR as the basis for their philosophical or methodological approach. This is problematic and suggests a lack of sophistication in the research approach of these students.

Although all theses used theories or frameworks from the knowledge base to inform their artifact design, few explicated those theories as their kernel theories or justificatory knowledge. Explanatory (kernel) theories informing DSR were scarce in these theses. Only seven theses explicated their underpinning theories as their *kernel* theories. Particularly in the context of DSR theses, one would expect to find design principles mentioned. Although 17 theses referred to design principles, only 11 of these reported actual use of design principles. This finding is consistent with that reported by Leukel et al. (2014), who found a "marginal role" for such foundations in the literature they surveyed. Leukel et al. found "little evidence for deriving design elements from existing theories," a finding consistent with our research.

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

We acknowledge that there is a broad range of possible outputs of doctoral DSR projects. While all IS doctoral theses may be expected to have academic outputs and contribute to theory and practice, DSR theses should also produce artifacts and design theory. We consider academic outputs, artifacts, design theory and contributions to practice reported in the doctoral theses as valid outputs.

It has been suggested that publishing DSR results in the best journals is a challenge (e.g., Conboy, Fitzgerald, & Mathiassen, 2012). Nineteen of the theses contributed a total of 41 journal papers; of those, seven were published in Quartile 1 (Q1) journals (according to SJR's[1] ranking), eight in Q2 journals, six in Q3 journals, and four in Q4 journals. The remaining 16 were published in unranked journals. Candidates also reported that 138 papers from their research had been published in refereed conference proceedings. Clearly, while the work is being published, as argued elsewhere (e.g., Conboy et al., 2012), little of it seems to be appearing in the very *best* journals. Of course, this may also be due to the relative inexperience of our doctoral candidate subjects. Our analysis does not extend to include postgraduation publications. The broader issue of preparedness, in terms of publishing doctoral research, has been previously raised (Lyytinen, Baskerville, Iivari, & Te'eni, 2007), and Gregor and Hever (2013) offer relatively recent advice on the presentation of DSR for publication.

The four widely accepted artifact types were reported in our sample of theses in the same order of frequency as in the two previous literature reviews (Venter et al., 2015; Kotzé et al., 2015): the most frequent artifact type was method, followed by model, instantiation, and construct. One thesis (#20) highlighted the fact that some DSR authors (e.g., Hevner et al., 2004; Kuechler & Vaishnavi, 2008) appear to promote the idea that the artifact in IS design science must be a technological artifact (e.g., an IT component or IT representation).In their study, Kotzé et al. (2015) identified another artifact type, *framework*, which we also found reflected in our sample.

In this study we found outputs that included a broad mixture of artifact types including models, methods, instantiations, constructs, and frameworks. Our categorization of types of artifact and evaluation methods was not always straightforward and required author consensus during the analysis. In the majority of theses, the elements of DSR, e.g., artifact type, kernel theories, design principles, and evaluation methods were not explicitly articulated.

There are conflicting views from leading DSR academics about DSR nomenclature and, as a result, broad agreement has not been achieved on terminology, methodology, evaluation criteria, and other aspects (Baskerville, 2008; Venable, 2010, 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 difficulties in publishing the work (Peffers et al., 2018). Of course, the standard use of nomenclature in information systems research is a problem extending beyond DSR (Lee, 2010).

A theoretical contribution to the body of knowledge is expected in all IS doctoral theses and, specifically in DSR, a contribution to design theory should be considered (Baskerville, Baiyere, Gregor, Hevner, & Rossi, 2018). However, in 60% of the theses in our study, the claimed theoretical contributions did not include development of new theory nor did they extend/reexamine 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. While these findings can be justified from the pragmatic-camp or complementary approach (Gregor & Hevner, 2013), the lack of theoretical contribution is striking if the design-camp is used as the reference DSR approach.

Evaluation, while not an output per se, is certainly a distinguishing component of DSR, compared to other types of research. It not only validates the design (through internal mechanisms) but also the artifact itself (by reference to, for example, practitioners). We found that nearly 40% of the studies sought expert evaluation, about 40% used case studies, and just under one third used field studies, suggesting that industry and practitioners were active in evaluation activities. Almost all projects had some form of evaluation of the artifact, although almost one half stated that they encountered limitations on the number, availability, and diversity of participants for these evaluations. However, in the majority of the theses, the evaluation of the design, for example, the design principles and kernel theories, was not at all clear. Reference models and standards for such evaluations are becoming available (Pries-Heje, Baskerville, & Venable, 2008; Venable et al., 2012, 2016) but they were not reflected in the doctoral research projects in our study.

6 Conclusions

This paper focuses on the major challenges of conducting DSR in IS research, particularly regarding doctoral research. DSR is a relatively new paradigm in IS and its philosophical and methodological foundations are still evolving. Also, the attractiveness of DSR for junior researchers (e.g., doctoral candidates) and the position of DSR publications in top IS journals has been questioned by a number of scholars. This paper investigates the use of DSR in

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

doctoral studies in Australia to empirically examine these concerns, showing the range of the outputs of doctoral DSR projects and examining how existing DSR guidance has been applied by doctoral candidates.

A content analysis of 40 doctoral theses from 19 Australian universities was used to answer the research questions. The findings showed that DSR is being used by doctoral candidates to address sociotechnical and technical problems in a diverse range of industry settings. The underpinning research philosophy and the research methodology were found to be the most disputed issue among the candidates, disregarded in nearly half of theses and represented with a diverse range of philosophical views (e.g., pragmatism, interpretivism or realism) in the others. The outcome is surprising, as the importance of a philosophical foundation has been previously raised by DSR scholars (Goldkuhl, 2011; Niehaves, 2006; B. Niehaves, 2007). We also found it interesting that 33 out of 40 candidates considered DSR to be their research methodology, in spite of the ongoing debate on this premise. Our study found the work of Hevner et al. (2004) to be universally referenced by all 40 candidates and applied as guidance in 13 theses. Although 33 theses claimed to have followed one or more DSR guidelines, deviations from the guidelines were evident. As the design of artifacts distinguishes DSR from behavioral science research, it is encouraging to note that candidates adopted broader and innovative perspectives regarding the types of artifacts created. Those reported in the theses went beyond Hevner et al.'s (2004) list of four artifact types to include frameworks and theories. Among the wide range of evaluation methods used by candidates to evaluate the designed artifact, expert evaluation and case study were the most frequently used. Design principles were not frequently applied and key terminologies (e.g., artifact, model, design theory, case study) were used inconsistently. The doctoral candidates were able to publish their work in a large number of refereed outlets before graduation.

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 doctoral candidates, their supervisors, and the academic DSR community:

First, our analysis of the doctoral theses showed a considerable lack of understanding, or perhaps misunderstanding, of DSR among doctoral candidates. Considering the relative youth of design science, particularly in IS research, we argue that it is not as established as behavioral science research methods and there is still active debate on some fundamentals of DSR among leading scholars in this field. In fact, Margolin (2010) calls for discussion on core curricula across all doctoral programs that include design, including disciplines such as "engineering, architecture and computer science" (p. 74). Formal training in DSR would be helpful for doctoral students to overcome the current gap in DSR knowledge utilization and is highly recommended, particularly for doctoral programs that do not require coursework or that do not specifically include DSR in coursework. Formal training is offered in some American (Vaishnavi & Kuechler, 2015) and European universities (e.g., IT University of Copenhagen Technical University of Munich[2]) but not at most Australian universities.

Second, our study showed that most doctoral candidates are concerned with design, development, and evaluation of artifacts, but not with design theory. This is consistent with the view of Baskerville et al. (2018) who recently stated that artifact design usually precedes development of design theory. Typically, within the time constraints of PhD studies, the student may not have time to generate design principles after building and evaluating the artifact. We would recommend that supervisors plan a series of related research projects to provide sufficient time for iterative cycles of artifact(s) design, development, and evaluation, as well as subsequent generation of design theory. We recommend that candidates address design theory in postexamination publications, as failing to do so may be a limiting factor in terms of both realizing the goals of the doctoral studies and publishing in top-tier journals (Gregor & Hevner, 2013).

Third, we echo previous recommendations (e.g., Baskerville et al., 2018; Venable, 2010, 2015; Winter, 2008) and encourage the leading DSR scholars to work toward establishing commonly accepted research foundations for DSR in IS and commend the ISDSR Integrated Roadmap proposed by Deng and Ji (2018) in this regard. To improve DSR it will be necessary to clearly establish philosophical foundations, methodological issues, guidelines, reference models, and clearly defined terminology supported by adequate examples of what is and is not meant by any specific term (e.g., artifact, model, framework). While the current body of DSR literature was found to be

[2] For information on these two programs see *http://en.itu.dk/Research/PhD-Programme/PhD-Courses/PhD-courses-2016/PhD-Course---IT-Design-Science-Research* and *https://www.i17.in.tum.de/index.php?id=53&L=1*, respectively.

ambiguous and difficult to understand by doctoral students, it also proved problematic for us in terms of analyzing the data because different candidates used different terms to represent a single concept—for example, kernel theory. Peffers et al. (2018) highlight the many guidelines and objectives published in journals and conferences. They claimed that the lack of maturity of DSR in comparison to behavioral research approaches makes it difficult and costly to carry out DSR projects and publish DSR papers. We recommend that doctoral students explicate their DSR *genre* (Peffers et al., 2018) and follow processes, requirements, terms of evaluation, and presentation styles consistent with the specified genre to reduce the risk of prejudicial criticism during thesis examination or upon submission of papers for publication.

Fourth, DSR strives to achieve two different purposes in one research project at the same time: to produce scientific knowledge and solve a real organizational problem (Deng & Ji, 2018; Dresch, Lacerda, & Antunes Jr, 2014). Satisfying academic and industry stakeholder expectations can lead to projects that may suffer from too wide a project scope. One might question whether supervisors are, in fact, directing their students to properly scope and plan their design science PhD projects. If that is not the case, then we recommend that doctoral candidates should be mindful in defining the scope of their doctoral projects since significant DSR projects usually involve many researchers over several years (Gregor & Hevner, 2013). As such, an excessively wide project scope may prevent the researcher from adequately following DSR guidelines.

6.2 Limitations

As with any research, we recognize limitations in terms of the method used. The scope of the review of DSR studies is limited to 40 doctoral theses from 19 Australian universities. Within this sample, while Trove is the commonly used repository of doctoral theses completed in Australia, it is possible that some doctoral theses completed during our study period were not submitted to Trove. In addition, our search criteria may have failed to select some relevant 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 postgraduation publications by the doctoral candidates studied here.

The fact that only doctoral theses were studied is another limiting factor. We recognize that doctoral programs train the future leaders of the field. Many doctoral graduates, having finished their doctorate, will reflect on their lack of understanding and on what they should have done better or differently. Therefore, it is perfectly normal that doctoral theses of any type may not exhibit clear elucidation, philosophical nuance, and sufficient clarity.

6.3 Future Research

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

A topic for future research concerns the apparent inconsistency found in the adoption of published DSR reference models and standards. While our study revealed a gap between the guidance provided by DSR scholars (as knowledge producers) and approaches taken by doctoral candidates (as knowledge consumers), the question as to *why* such an adoption gap exists remains unanswered. Further empirical investigations would be required to find the factors that contribute to this problem. For example, future studies could explore the complexity of DSR, lack of clarification of fundamental concepts, unsettled debates, lack of formal training, limited time of a doctoral study, and the preferences of supervisors.

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

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Appendix A

Table A1. Analysis Codebook: Questions and Response Options

1.	Thesis title:
2.	Author :
3.	Year:
4.	University:
5.	What artifact was designed? a) Construct b) Model c) Method d) Instantiation e) Theory/Framework
6.	Evaluation method(s) used? **Category of Evaluation Method** — **Specific Evaluation Method** a) Observational — Case Study - Field Study b) Analytical — Static - Architecture - Optimization - Dynamic Testing c) Experimental — Controlled Experiment - Simulation d) Testing — Functional (Black Box) - Structural (White Box) e) Descriptive — Informed Argument - Scenarios f) No evaluation — None
7.	Evaluation timing/setting? a) Naturalistic b) Artificial c) Ex ante d) Ex post
8.	What DSR literature was cited?
9.	What DSR guidance was followed?
10.	Were the design principles presented? a) Yes b) No
11.	Was a kernel theory used? a) Yes b) No
12.	Did the artifact lead to claims of new theory or reconsideration of existing theory? a) New b) Extending/testing existing theory
13.	Nature of research? a) Technical b) Sociotechnical c) Organizational
14.	Targeted sector/industry?
15.	Geographic domain of the study?
16.	Number of peer-reviewed publications? a) Journal papers: b) Refereed conference/workshop papers: c) Book chapters:
17.	What research philosophy underpins the study?

Appendix B

Table A2. Details of Australian Doctoral DSR Theses Retrieved for Analysis

#	Candidate	Title	Year	University*	Faculty/School	Award	Search criteria		
							A	B	C
1	Matus-Castillejos, A.	Management of time series data	2006	UC	School of Info Science & Engineering	DIT	✓		
2	Nyaga, C. K.	A design science approach to developing and determining web site quality dimensions for the public accounting profession	2007	ECU	Faculty of Business & Law	DBA	✓		
3	Valverde, R.	The ontological evaluation of the requirements model when shifting from a traditional to a component-based paradigm in information systems re-engineering	2008	USQ	School of IS	DBA		✓	
4	Ducrou, A. J.	Complete interoperability in healthcare: Technical, semantic and process interoperability through ontology mapping and distributed enterprise integration techniques	2009	UOW	Faculty of Informatics	PhD	✓		
5	La Rosa, M.	Managing variability in process-aware information systems	2009	QUT	Faculty of Science & Technology	PhD	✓	✓	
6	Redding, G. M.	Object-centric process models and the design of flexible processes	2009	QUT	Faculty of Science & Technology	PhD		✓	
7	Nantiyakul, R.	Using a design-science approach for effective corporate performance management systems development	2009	Monash	Centre for Decision Support and Enterprise Systems Research	PhD		✓	
8	Pearson, N.H.	An evaluation of IS-impact utility and intuitiveness	2010	QUT	Faculty of Science & IT	PhD	✓	✓	
9	Gao, S.	Exception management in logistics: An intelligent decision-making approach	2010	UQ	UQ Business School	PhD	✓		
10	Xie, J	A user-sensitive resource quality assessment approach for health information portals	2011	Monash	Faculty of IT	PhD	✓		
11	Fung, K. H.	A method engineering approach to support dynamic evolution in composition-based distributed applications	2011	UNSW	School of IS, Technology & Management	PhD	✓		
12	Jones, D. T.	An information systems design theory for e-learning	2011	ANU	College of Business & Economics	PhD			✓
13	Grigsby, S. A.	A context sensitive, advisory decision support approach	2011	Monash	Faculty of IT	PhD	✓		

#	Candidate	Title	Year	University*	Faculty/School	Award	Search criteria		
							A	B	C
		for mobile, knowledge based, time critical environments							
14	Gibson, M	Evaluating the benefits of business intelligence information systems: A design science approach	2011	Monash	Faculty of IT	PhD	✓	✓	
15	Adams, R.	The advanced data acquisition model (ADAM): A process model for digital forensic practice	2012	Murdoch	School of IT	PhD	✓		
16	Permvattana, R.	The VIVID model: Accessible IT e-learning environments for the vision impaired	2012	Curtin	School of IS	PhD	✓		
17	Finney, K.T.	Ontology management and selection in re-use scenarios	2012	UTAS	School of Computing & IS	PhD	✓		
18	Omar, M. F.	The structured and practical approach in development of decision support system for consultant selection in public sector infrastructure project	2012	QUT	School of Civil Engineering & Built Environment	PhD	✓		
19	Pigott, D.	A perspective and framework for the conceptual modelling of knowledge	2012	Murdoch	Not stated	PhD	✓		
20	Ploesser, K.	A design theory for context-aware information systems	2013	QUT	IS School, Faculty of Science & Engineering	PhD	✓	✓	✓
21	Md Ali, A.	Web interactive multimedia technology in university learning environments	2013	RMIT	School of Bus Info Technology & Logistics	PhD	✓		
22	Meersman, D.	Domain-driven innovation: Principles and practice	2013	Curtin	School of IS	PhD	✓		
23	Gacenga, F. N.	A performance measurement framework for IT service management	2013	USQ	School of IS	PhD	✓		
24	Cheung, R. C. T.	Adoption and use of collaborative technologies for project-based learning	2013	UniSA	International Graduate School of Business	PhD	✓		
25	Adikari, S.	User experience modelling for agile software development	2014	UC	Faculty of Information Sciences & Engineering	PhD	✓		
26	Esmaeil Zadeh, M.	Using the viable system model to derive methods for developing principles of enterprise architecture	2014	UNSW	School of Engineering & IT	PhD	✓	✓	
27	Wong, A. K. L.	Investigating a shared co-located digital collaborative space for learning entity-relationship modelling	2014	Monash	Faculty of IT	PhD	✓		

#	Candidate	Title	Year	University*	Faculty/School	Award	Search criteria		
							A	B	C
28	Hellmuth, W. J.	Design theory for innovation of classroom-based information systems	2015	QUT	Science & Engineering Faculty	DIT	✓		
29	Cassidy, L. J.	Website benchmarking: a tropical tourism analysis	2015	JCU	Science & Engineering Faculty	PhD	✓		
30	Shrestha, A.	Development and evaluation of a software-mediated process assessment approach in IT service management	2015	USQ	School of Management & Enterprise	PhD	✓		
31	Raphiphan, P.	A context-aware traffic congestion estimation framework to overcome missing sensory data in Bangkok	2015	Monash	Caulfield School of IT	PhD	✓		
32	Feris, M.	Enhancing the quality of planning of software development projects	2015	ANU	College of Business & Economics	PhD	✓		
33	Shih, S-Y	Challenges associated with implementing BIM-enabled code-checking systems within the design process	2015	UON		PhD	✓		
34	Jafarov, N	Viable enterprise service bus model: A model for designing a viable service integration platform	2016	UNSW	School of Engineering and Information Technology	PhD	✓		
35	Rani, Y.	Analysing smart metering systems from a consumer perspective	2016	ANU		PhD	✓		
36	Amirebrahimi, S.	A framework for micro level assessment and 3D visualisation of flood damage to a building	2016	UniMelb	Department of Infrastructure Engineering	PhD	✓	✓	
37	Raftopoulos, M	How organisations play: Creating stakeholder value with enterprise gamification	2016	RMIT	School of Media and Communication	PhD		✓	
38	Rehn, A. J.	Input-centric profiling and prediction for computational offloading of mobile applications	2016	JCU	College of Business, Law and Governance	PhD	✓		
39	Amrollahi, A.	An online collaborative approach for strategic planning	2016	Griffith	School of Information and Communication Technology	PhD	✓		
40	Laylavi, F.	A framework for adopting Twitter data in emergency response	2017	UniMelb	Department of Infrastructure Engineering	PhD	✓		

* Universities: ANU Australian National University; Curtin University; ECU Edith Cowan University; Griffith University; JCU James Cook University; Monash University; Murdoch University; QUT Queensland University of Technology; RMIT Royal Melbourne Institute of Technology; UC University of Canberra; UniSA University of South Australia; UniMelb University of Melbourne; UNSW University of New South Wales; UON University of Newcastle; UOW University of Wollongong; UQ University of Queensland; USQ University of Southern Queensland; UTAS University of Tasmania.

Appendix C

Table A3. DSR Guidance Followed by Australian Doctoral Candidates

Thesis #	1	2	3	4*	5*	6	7	8*	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Citations	Guidance
Year Published	2006	2007	2008	2009	2009	2009	2009	2010	2010	2011	2011	2011	2011	2011	2012	2012	2012	2012	2012	2013	2013	2013	2013	2013	2014	2014	2014	2015	2015	2015	2015	2015	2015	2016	2016	2016	2016	2016	2016	2017		
Reference																																										
Nunamaker & Chen (1990)	**X**		X												X												X						X						X		6	1
Nunamaker, Chen, & Purdin (1990)	X						X		X	X		X		X				X	X			X																			9	0
Walls et al. (1992)							X		X	X	X	X		X				X	X	X				X		X				X				X		X				X	15	0
March & Smith (1995)	**X**	X	**X**	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X				X	X		X	X	X	X			X	X	29	2
Burstein & Gregor (1999)	X		X					X		X	X	X																													6	0
Gregg, Kulkarni, and Vinzé (2001)	**X**								X			X		X					X																						5	1
Purao (2002)	X	X								X																X							X	X					X		7	0
Gregor (2002)								X			X	X											X											X					X		6	0
Walls et al. (2004)												X		X																X				X					X		5	0
Collins, Joseph, & Bielaczyc (2004)																								X																	1	0
Vaishnavi & Kuechler (2004)	X	X					X				X						X			X						X			X	X	X	X		X					X		13	0
Hevner et al. (2004)	X	**X**	X	X	X	**X**	**X**	X	**X**	**X**	X	X	**X**	**X**	X	X	**X**	X	X	X	X	X	X	X	X	**X**	X	X	X	X	X	X	**X**	**X**	X	**X**	**X**	X	X	X	40	13
McKay & Marshall (2005)		X										X		X	X		X									X															5	0
Peffers et al. (2006)																																**X**									1	1
Venable (2006)							X			X		X			X	**X**					**X**	**X**						X		X									X		10	3
Gregor (2006)								X			X	X							X	X	X		X			X								X					X		10	0
Carlsson (2007)																														X											1	0
Gregor & Jones (2007)							X		X			X	X				X		**X**	X			X	X	X	X				X									X		13	1

Thesis #	1	2	3	4*	5*	6	7	8*	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Citations	Guidance
Year Published	2006	2007	2008	2009	2009	2009	2009	2010	2010	2011	2011	2011	2011	2011	2012	2012	2012	2012	2012	2013	2013	2013	2013	2013	2014	2014	2014	2015	2015	2015	2015	2015	2015	2016	2016	2016	2016	2016	2016	2017		
Reference																																										
Iivari (2007)												X		X			X		X	X					X					X									X		8	0
Björn Niehaves (2007)																																							X		1	0
Peffers et al. (2007)										X	X		X		X			X	X		X		X			X	X	X	X	X			X	X	X	X	X	X	X	X	21	8
Hevner (2007)							X																		X			X		X	X				X		X				7	0
Vaishnavi & Kuechler (2007)																		X	X							X		X			X			X							6	2
Pries-Heje et al. (2008)										X							X		X									X		X		X	X		X			X		X	10	0
Baskerville (2008)							X					X					X					X										X									5	0
Kuechler & Vaishnavi (2008)										X		X			X				X	X	X				X	X				X				X					X		11	0
March & Storey (2008)																												X													1	0
Baskerville et al. (2009)																												X		X					X						3	0
Cleven, Gubler, & Hüner (2009)															X								X												X			X		X	5	0
Iivari & Venable (2009)										X		X									X							X													4	0
Gregor (2009)																			X				X			X								X							4	0
Offermann, Levina, Schönherr, & Bub (2009)																											X														1	1
Hevner & Chatterjee (2010)										X					X		X		X	X				X	X	X			X				X	X							11	2
Venable (2010)																																X									1	
Alturki, Gable, & Bandara (2011)																												X						X						X	3	1
Carlsson, Henningsson, Hrastinski, & Keller (2011)																														X											1	
Kuechler & Vaishnavi (2011)																													X	X											2	

Thesis #	1	2	3	4*	5*	6	7	8*	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Citations	Guidance
Year Published	2006	2007	2008	2009	2009	2009	2009	2010	2010	2011	2011	2011	2011	2011	2012	2012	2012	2012	2012	2013	2013	2013	2013	2013	2014	2014	2014	2015	2015	2015	2015	2015	2015	2016	2016	2016	2016	2016	2016	2017		
Reference																																										
Österle et al. (2011)																														X											**1**	
Beck, Weber, & Gregory (2013)																																							X		**1**	
Peffers et al. (2012)																														X					X			X			**3**	
Kuechler & Vaishnavi (2012)																				X														X					X		**3**	
Venable et al. (2012)																														X		X	X		X			X		X	**6**	
Venable & Baskerville (2012)																																X	X								**2**	
Gregor & Hevner (2013)																									X	X				X		X	X					X	X		**7**	
Myers & Venable (2014)																																							X		**1**	
Prat, Comyn-Wattiau, & Akoka (2014)																														X											**1**	
Vaishnavi & Kuechler (2015)																																X	X								**2**	
Lee, Thomas, & Baskerville (2015)																																							X		**1**	
Total citations DSR literature	**8**	**5**	**4**	**2**	**1**	**1**	**9**	**5**	**6**	**12**	**8**	**16**	**4**		**9**	**3**	**9**	**6**	**14**	**10**	**6**	**5**	**7**	**5**	**8**	**14**	**4**	**10**	**5**	**21**	**5**	**10**	**11**	**15**	**9**	**4**	**3**	**7**	**19**	**8**		**36**

Legend:

*	No Guidance is used – thesis cited DSR reference but did not explicitly apply guidance.
X	Cited
X (shaded)	Used as Guidance
(hatched)	Not yet published at time of thesis completion.

About the Authors

Aileen Cater-Steel is an emeritus professor of information systems at University of Southern Queensland. Aileen's research interests include IT service management (ITSM), IT standards and governance, e-learning systems, and IT outsourcing. She was lead chief investigator on two ITSM projects that achieved funding from the Australian Research Council. She has published in top journals and co-edited five research books. Her work has been recognized with a citation from the Australian Learning & Teaching Council for outstanding contribution to student learning. Prior to her academic appointment, Aileen worked in the private sector and government organizations where her career progressed from programmer to IT manager. She is a fellow of the Australian Computer Society (ACS), and graduate member of the Australian Institute of Company Directors.

Mark Toleman holds a joint appointment as university secretary and professor of information systems, at the University of Southern Queensland, Australia (USQ). From 2006-2012 he was a professor and head of the School of Information Systems and chair of the Academic Board at USQ. He was the director of the E-business Advisory and Research Centre at USQ from 2003-2005 and from 2000-2006 he was an associate professor and deputy chair of the Academic Board. Toleman has a PhD in computer science (human-computer interaction) from the University of Queensland and an MSc in mathematics from James Cook University. He was president of the Australian Council of Professors and Heads of Information Systems from 2009-2012. Toleman is a member of the Australian Institute of Company Directors, the Australian Computer Society, the Association for Information Systems, and IFIP Working Groups 8.6 and 13.1. He has published over 170 peer-reviewed articles in diverse areas ranging from information systems to human-computer interaction to agricultural science.

Mohammad Mehdi Rajaeian is a lecturer at the Australian Catholic University, Australia. He received a BSc in industrial engineering and an MBA from Sharif University of Technology, Iran, and a PhD in information systems from the University of Southern Queensland, Australia. His research interests include decision support systems, business intelligence, design science research, IT outsourcing, digital transformation, system theory, and the research-practice gap.