

# Towards a Pluralist Approach in Design Science: Case Study of an Agricultural DSS

Dale Mackrell

Griffith Business School, Griffith University, Brisbane Australia

[d.mackrell@griffith.edu.au](mailto:d.mackrell@griffith.edu.au)

Sue Nielsen

School of Information and Communication Technology, Griffith University, Brisbane Australia

[s.nielsen@griffith.edu.au](mailto:s.nielsen@griffith.edu.au)

**Abstract.** Multiple standpoints on design science exist. In this paper, the authors espouse a pluralist approach to design science, allowing an interpretive view of the human factors to complement the more prescriptive view of the IT artefact. To better comprehend the processes of IT design, development, practice, and incremental improvement, a study of CottonLOGIC, an agricultural decision support system (DSS) for the Australian cotton industry, was reassessed from a design science framework. In the study, the duality of technology, Orlikowski's (1992) adaptation of the social science theory, structuration theory, was used as the overarching perspective to overcome the dichotomy between technology as an objective force and technology as a socially constructed product which the study found to be inextricably linked. The contribution of the paper is to advocate a pluralist approach in design science thus allowing both the immediate situation and the wider context of agricultural institutions and environment to be taken into account in the interpretation of the users' proposals for improvements to the DSS, while not ignoring the functionality of the IT artefact.

## 1 Introduction

The nature and scope of theory in design science is far from resolved and some standpoints remain vehemently polarised, ranging from the exclusion of theory (March et al 1995, p.258) to the integration of positivist theory for prediction (Venables 2006, p.12) to a pluralist approach where social science theories of an interpretivist persuasion balance prescriptive views of design science to reveal the human attitudes and activities embedded in the technical artefact (McKay et al 2005; 2007).

This paper considers principles of design science in reviewing a study (Mackrell et al 2009; Mackrell et al 2007) of an agricultural decision support system, CottonLOGIC, in the Australian cotton industry. The experience of the authors (Mackrell et al 2009) was that a multi-paradigmatic perspective was required in order to account for and understand the range of influences and processes which were involved in IT design, development, and use. The study discussed in this paper adopted Orlikowski's (1992) approach to technology in structuration, termed the duality of technology, as the meta-theory for investigating human interaction with technology to overcome the dichotomy between technology as an objective

force (its 'constitutive role') and technology as a socially constructed product (its 'constituted nature').

Iivari's assertion that existing artefacts are one of the major sources of ideas for design research and that "most design research consists of incremental improvements to existing artefacts" (Iivari 2007, p.52) is apt. Iivari (2007) refers to Popper's (1978) three worlds as a good starting point for a sound ontology of design science. Orlikowski's (1992) duality of technology allowed an exploration of the interaction between World 2 (the consciousness and mental states of the developers and users) and World 3 (the institutions of the Australian cotton industry and farming practices).

This paper also addresses the problems expressed by Hevner et al (2004, p.98); that "the dangers of a *design science* research paradigm are an overemphasis on the technological artefacts and a failure to maintain an adequate theory base, potentially resulting in well-designed artefacts that are useless in real organizational settings" while "the dangers of a *behavioural science* research paradigm are overemphasis on contextual theories and failure to adequately identify and anticipate technological capabilities ...".

In brief, the authors of this paper appraise various arguments regarding the inclusion or exclusion of theory, in particular social science theory, in design science research. Insights gained from re-evaluating the study of CottonLOGIC from the design science perspective are discussed. The contribution of this paper is to extend earlier research by McKay et al (2005; 2007) which argued for design science as a broad pluralistic body of knowledge.

## **2 Perspectives on Design Science**

According to Iivari (2007), design science research has been in practice in IS for decades where it has been characterised as the socio-technical approach. Iivari (2007) as well as Gregor et al (2007) explained that, until recently, research in the design science field has been sparse because of the domination of the North American-led focus on prescriptive theory-based research rather than studies of the technical artefact per se. Orlikowski and Iacono (2001, p.121) offered a broad description of technical artefacts which they defined as "bundles of material and cultural properties packaged in some socially recognisable form such as hardware and /or software". These authors found that most IS research identified technology as 'black boxes' and failed to look at the process, product or ensuing practice. Consequently, Orlikowski and Iacono (2001) were leaders in a call for a return to investigating the technology artefact as a core subject in IS research. The authors of the study (Mackrell et al 2009) discussed in this paper supported this view of the IT artefact, in that it was difficult to untangle the functionality of the DSS from the institutional factors which had influenced its design, namely, the regulation of the Australian cotton industry and the cotton growers' perceptions of best practice.

There is considerable debate in IS as to the extent of the influence of the social and the technical (McKay et al 2007, p.611). Hevner et al (2004, p.100) propounded that design science and social/behavioural sciences are complementary, that is, design science is "active with respect to technology" but often takes "a simplistic view of the people and the organizational contexts ...". All the same, some proponents of the design science approach

supported the exclusion of the social (particularly the interpretive paradigm) to focus on the IT artefact, its design, development and practical utility (Purao 2002, p.20). As mentioned above, this dichotomy appeared fruitless to the authors because of the impossibility of separating the artefact from the circumstances within which it was designed, used and improved.

The role of theory in design science has been the topic of considerable debate, and the use of theory and theorising is not always encouraged (Venable 2006). Venable (2006, p.1) explained that some authors explicitly exclude “theory development and testing from design science, leaving them to the natural and social/behavioural sciences”. Indeed, March et al (1995, p.258) argued that theory is not part of design science. These authors envisaged design science and natural science as a dualism; that “research activities in design science are twofold: build and evaluate” while “research activities in natural science are parallel: discover and justify ...”. Venable (2006, p.3) contended that theory should be a primary output as an evaluative step in design science and needs to be predictive in order to make recommendations on the efficiency, effectiveness, usefulness or other utility characteristic of the artefact. Meanwhile, Walls et al (1992), from an empirical study in the context of an executive information system, argued that design science should encompass prescriptive theories from various disciplines including social science.

## **2.1 Interpretivism in Design Science**

Nevertheless, there are strong advocates for an interpretive approach in design science. Carlsson (2007 p.79) insisted that design science research in IS should include organisations, people, and IT artefacts while Iivari (2007, p.51) expressed concern that creativity and innovation may be suppressed by a rigorous systems development methodology based on positivist assumptions. Iivari (2007, p.54) insisted that design science research does not need to be essentially positivist and that the construction of “IT artefacts may differ in their ontological and epistemological assumptions”. Iivari (2007, p.52) declared that it is well-known that customers are a source of innovation therefore relevance increases when the problem to be solved is a practical one. This idea is strongly supported by the study of CottonLOGIC where the users showed considerable insight into the usefulness of the DSS not only for farm management but also for the welfare of the cotton industry.

Vaishnavi et al (2007, p.2) recognised IS as belonging to a multi-paradigmatic research community. The pluralistic perspective is also endorsed by Purao (2002, p.25 citing Banville et al 1989) who insisted that the IS discipline is best served by a pluralistic model rather than a monistic view of science. Gregg et al (2001) went so far as to propose the socio-technical as a fresh paradigm for developmental research to complement the existing positivist and interpretivist paradigms. Meanwhile, Carlsson (2007, p.80-81) who claimed that “IS design science research should produce knowledge in the form of design propositions”, which should be “...used by practitioners, it should be applicable and actionable ... means grounding in results and theories from the natural and behavioural sciences”. Vaishnavi et al (2006, p.11) explained that the philosophical assumptions of a research designer moves through stages from “constrained construction” when creating the artefact, to positivism when predicting and making recommendations, and finally to interpretivism when observations become the basis

of new theories. These philosophical assumptions are illustrated in table 1 below (Vaishnavi et al 2006, p.12).

Basic Belief	Research Perspective		
	Positivist	Interpretive	Design
Ontology	A single reality. Knowable, probabilistic	Multiple realities, socially constructed	Multiple, contextually situated alternative world-states. Socio-technologically enabled
Epistemology	Objective; dispassionate. Detached observer of truth	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	<i>Knowing through making</i> : objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology	Observation; quantitative, statistical	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure <u>artifactual</u> impacts on the composite system.
Axiology: what is of value	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e. improvement); understanding

Table 1: Philosophical assumptions of three research perspectives (Vaishnavi et al 2006, p.12)

Bratteteig (2007, p.71) also sanctioned the “... inclusion of many different sciences in our theoretical and methodological repertoire” while Niehave (2007, p.106) posited that “design science research is not only a positivist domain, but also open to alternative epistemologies”. Puroo (2002, p.16) claimed that “once created, the options of a positivist or interpretivist stance are open for studying the artefact”. In an example, Puroo (2002, citing Orlikowski 1992) claimed that an artefact may be studied in the context of use using an interpretive lens. It was Puroo (2002, p.20) who identified a gap, namely, the contribution of social science to the design science domains of theory and knowledge. Indeed, there is an opportunity to recognise a synergy between design science (with its more functionalist and constructionist perspective) and social science (with an interpretive and qualitative perspective).

This paper proposes that a pluralist approach through the interaction of an interpretive social science theory with the more functionalist design science methodology may overcome these problems. This paper seeks to offer a response to Niehaves’ queries “Is design science open to diverse epistemologies?” and “How does the discussion of design science relate to the discussion of epistemology, for instance positivism and interpretivism?” (2007, p.101).

### 3 Research Context, Design and Methodology

In this section, the research design of the CottonLOGIC study is described as well as the research site and the technical artefact under investigation, which was an agricultural DSS developed for the Australian cotton industry.

#### 3.1 Research Context

The Australian cotton industry today is confronted with a multitude of changes. The primary concern

is still maximising the cotton yield, controlling production costs while ensuring cotton quality, and seeking optimum market prices. Yet environmental sustainability has become an

imperative in the cycle of production. Cotton growers and their advisors are conforming in increasing numbers to self-regulatory practices such as Best Management Practices (BMP) and Integrated Pest Management (IPM). Furthermore, cotton growers and their advisors need to adjust to the growing of new insect resistant, transgenic (genetically modified) cotton seed varieties such as Ingard® and Bollgard II®, introduced as IPM initiatives to limit harmful spraying regimes (The Australian Cottongrower 2006). Innovative technologies such as the agricultural computer-based decision support systems (DSS) CottonLOGIC are considered keys to the adoption of sustainable farming systems.

CottonLOGIC is an advanced farm management suite of software programs to aid the management of cotton production. The software was developed in Australia in the late 1990s by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Cotton Cooperative Research Centre (CRC), with support from the Australian Cotton Research and Development Corporation (CRDC). CottonLOGIC consists of record-keeping and decision support modules to assist cotton growers and their advisors in the management of farm operations, cotton pests and soil nutrition. Mackrell et al (2009) in the study of CottonLOGIC found that the design into record-keeping and decision support modules contributed to adoption and implementation success. The study found that growers are more likely to use the record-keeping modules for recording crop inputs and yields, while cotton industry professionals are more inclined to use the decision support modules which contain models to predict soil nutrition and the populations of insect pests such as the heliothis moth. As mentioned above, the institutional circumstances and the participants' perceptions of them are inextricably linked to the development, design, and evaluation of the DSS artefact. Hence the need for a broad perspective on the design and development problem.

### **3.2 Research Design and Methodology**

Although the study referred to in this paper was not initially perceived as a design science project, it has been useful to review the work in that light. In that regard, the study fits into the design cycle as proposed by Hevner et al (2007, p.88) with the evaluation steps referred to by McKay et al (2005, p.7) as an “ideal process for the conduct of design research”.

The research methodology of the study was qualitative thus letting the social world of cotton growing be understood contextually through the first-hand knowledge of participants, in a manner described by Walsham (1995). The rationale for a qualitative study was that an in-depth study of a situated experience would provide deeper understanding of the complexity of the situation; that insufficient was known about the design and use of CottonLOGIC to justify gathering standardised quantitative data from a large sample of the population. The study is steeped in an interpretive paradigm, and as such, themes have emerged from the interview data rather than being pre-determined beforehand as questions for a survey would have been (Patton 2002).

The unit of analysis was at the individual level, predominantly the Australian cotton grower in their roles on family cotton farm. To improve understanding of the influences on software

design and practice, a range of informed industry professionals were consulted for their perceptions of growers' roles in farm management and therefore the requirements for a DSS.

All participants were selected according to a purposeful sampling strategy. The cotton growers were selected based on the following criteria: 1) farmed in the Australian eastern states of Queensland or northern New South Wales; 2) were responsible for, that is, owned and/or managed family farms irrespective of size (as distinct from farms owned by large corporations); 3) indicated an awareness of environmentally sustainable and high-technology farming practices; and 4) were registered on a CottonLOGIC and/or Wincott (Women in Cotton Industry Network) database. The cotton industry professionals were cotton agronomists and consultants, rural extension officers, researchers and educators, rural experimental scientists and CottonLOGIC developers who were located in Queensland or northern New South Wales. As professionals, all these participants had to have some knowledge of agricultural DSS either through development, usage, research or teaching, and, to some extent, were observers and/or advisors of cotton growers.

Data gathering took place during three field studies and one telephone study with 32 participants over three years (2002, 2003, 2004). An interview guide was prepared to steer the interviews which were conducted at locations selected by participants, with each interview lasting at least an hour, and recorded on audio tape with permission. Interviews alternated between semi-structured and conversational depending on circumstance: semi-structured when the interviewee needed considerable guidance, and conversational when that was not the case. Usually, interviewees told their story without needing much intervention from the interviewer. Notes on each interview were recorded daily in an activity log and interviews were transcribed from audio tape into Microsoft Word as soon as possible.

Analysis was manual rather than computer-assisted since the number of interview transcripts was workable and the obligation to stay closely connected with the data was fundamental. Codes used in analysis were based on concepts or themes drawn from both the literature and theoretical framework. In short, this study of cotton growers using farm management software in the Australian cotton industry was an interpretive single case using ideographic methods. It allowed a first-hand investigation, involving several field trips to study participants in their natural setting, taking place over an extended period of time, and producing a textual analysis of rich insights after a period of reflection.

## **4 Data Analysis**

In this section, the analysis of the interview transcripts pertaining to CottonLOGIC design and development is provided. The analysis was informed by the theory of the duality of technology developed by Orlikowski (1992) from the social science theory, structuration theory, to further understanding of the technical artefact in organisations.

### **4.1 Evaluating Design and Development in the Context of Situated Use**

As mentioned earlier, Orlikowski and Barley (1991, p.151) and Orlikowski (1992) disagreed with the dichotomous perspectives on technology, as either an objective force or a socially

constructed product, and proposed the duality of technology theory for investigating human interaction with technology design, and development, and use.

According to Orlikowski (1992, p.410), in the *design and development* mode, “human agents build into technology certain interpretive schemes, certain facilities, and certain norms” while in the *use* mode, “human agents appropriate technology by assigning shared meanings to it, which influences their appropriation of the interpretive schemes (rules reflecting knowledge of the work being automated), facilities (resources to accomplish that work), and norms (rules that define the organisationally sanctioned way of executing that work) designed into the technology, thus allowing those elements to influence their task execution” (Orlikowski 1992, p.410).

**Realm of social structure**

In the design and development of agricultural DSS such as CottonLOGIC, system developers were informed by users (growers and professionals), by industry ideologies such as BMP and IPM, and by technological advancements. CottonLOGIC became a dominant IS in the industry.

**Modalities**

Agricultural DSS such as CottonLOGIC provided stocks of knowledge to support appropriate responses and shared meanings in the production and reproduction of cotton industry environmentally sustainable practices.

**Realm of human action**

System developers embedded meaning and understanding of industry sanctioned practices within the DSS. This was transferred to users in their interaction with the software and with each other. Users were empowered from their use of CottonLOGIC and their experiences were relayed back to the systems development team.

Table 2: CottonLOGIC: Duality of Technology framework for design and development in situated use (adapted from Orlikowski et al 1991, p.161)

The structure of this section of the paper is in two parts. The first part discusses design suggestions by users of features for incorporation into future versions of CottonLOGIC. The second part is a response by a software developer as to the development potential of those suggestions. Extracts of quotations of interviewees are provided as evidence.

**Design Proposals**

Kirsten, a cotton consultant, was keen to do comparative analyses of chemical sprays between clients’ farms for the benefit of her clients.

**Kirsten (cotton industry professional):** There’s a need to do comparative analysis on each farm including insecticides and defoliantes.

While having access to a centralised or distributed database for comparative analysis purposes was useful for consultants, it was not generally requested by growers, except Steve. Steve, a long-time user of CottonLOGIC, recognised that a centralised database would be helpful in servicing future Area Wide Management (AWM) endeavours allowing communities to work together to combat insect pests. CottonLOGIC, when redeveloped from the original agricultural DSS named SIRATAC, was built for PCs as a standalone DSS.

**Steve (cotton grower):** How we are trying to structure AWM is leading us back to SIRATAC with a centralised database.

Despite the request for a centralised database, Steve was typical of the growers who sought some way of integrating into one package the various functions deployed on the farm by modern technologies such as soil and yield monitoring by global positioning systems (GPS), field mapping by geographic information systems (GIS), and insect density simulation by DSS. He thought that Web capabilities might accomplish an amalgamation of tasks.

**Steve (cotton grower):** I think that the Internet structure should be the structure we should be revolving around to make it widely more accessible ... if we can find a system that ties all this research [GPS, GIS, DSS] together ....

Russell, an on-farm agronomist located in rural New South Wales, also supported the design of CottonLOGIC as Web-enabled since the data needed to be accessible by the main office in Sydney as well as in the cotton producing areas. CottonLOGIC, as software on a desktop computer, did not easily offer this option except by emailing the files.

**Russell (cotton industry professional):** Ultimately we'd like to have it web-based. It's no use it sitting on my computer only, because then the Sydney people can't access it.

Russell had been using CottonLOGIC intensively and with confidence. He now considered its heliothis simulation models less relevant and reliable since the advent of genetically modified cotton seed varieties such as Bollgard® with built-in resistance to the heliothis menace. Russell had depended on the integrated pest management (IPM) principles embodied within CottonLOGIC. Now he expressed uncertainty.

**Russell (cotton industry professional):** We've practised IPM on conventional country. How does that relate to Bollgard® now? We'll have to learn IPM all over again with probably a little less record-keeping.

Kylie, a consultant, remarked about the situation of growers forced by circumstances to diversify their production from a single crop to multi-cropping or grazing.

**Kylie (cotton industry professional):** I think we're moving from a cotton-specific program mainly because I don't think there are many growers who are cotton-specific.

Some users requested changes for CottonLOGIC which were related to the insect models. Lucy, an on-farm agronomist, thought that the cotton plant mapping features of CottonLOGIC should be easier to use.

**Lucy (cotton industry professional):** ... They've got a plant mapping thing on CottonLOGIC that could do with being a little bit more user-friendly. And with Bollgard®, plant mapping is fairly important.

Finally, some of the requested amendments were quite simple. In the case of Lucy, an on-farm agronomist, she wanted the flexibility to specify both acres and hectares in data entry.

**Lucy (cotton industry professional):** ...just the conversion from hectares to acres 'cause it works in hectares and we use acres a lot.

It was evident from the analysis above that growers and professionals, as knowledgeable and reflexive agents, constantly engaged with the software during use. For example, cotton growers and professionals alike used only the modules of CottonLOGIC that suited their purposes. Overall, they demonstrated remarkable creativity while using CottonLOGIC as they adapted it to their farming goals. Growers and professionals were aware of the complexity of the problems facing the industry and were mindful of industry sanctioned schemes embedded in the software such as BMP and IPM. Many users criticised CottonLOGIC's heliothis models, claiming they were no longer relevant in the pest management setting endorsed by the industry. Users' expectations led to proposals for software enhancement such as a Web-enabled multi-functional yet integrated CottonLOGIC with global positioning systems (GPS) and geographic information systems (GIS) as well as updated DSS pest simulation models.

While there were a lot of similarities, there were several distinctions between growers and professionals regarding the use of CottonLOGIC and in requests for amendments to the software. The professionals such as consultants and agronomists were more intent than the growers in entering the spray and insect count data, performing the insect pest modelling, and their reporting specifications were more specific. For example, consultants requested the capability to generate comparative analysis of clients' farms. By contrast, growers were focused on the recording of farming operations, especially on a multi-crop basis, and were more tolerant of CottonLOGIC's insect pest modelling than were the professionals.

### **Development Perspectives**

The main responsibility of the Cotton Management Support Systems (CMSS) team is the development, maintenance, delivery, and support of the cotton DSS program. Even so, the members of the CMSS team demonstrated a comprehensive understanding of who the users of CottonLOGIC were and how the software was used. Jack, a software developer in the CMSS, recognised that growers and professionals used only modules of CottonLOGIC that were relevant to their purposes.

**Jack (cotton industry professional):** We have quite a few bases that CottonLOGIC is supplied to such as consultants, growers, and researchers. Within each of those stakeholders,

there are still different groups such as even amongst the growers there are your corporate farms. These groups use different part of the software.

Jack recognised that the modularity of the software was a key to producing a DSS which addressed specific rather than generic needs of users. This approach is supported by the definition of a DSS which is “usually built to support the solution of a certain problem or to evaluate an opportunity” (Turban et al 2007, p.88).

**Jack (cotton industry professional):** We want to make CottonLOGIC a much more modularised system, having lots of different tools within a suite of applications. We’re essentially re-developing CottonLOGIC and because we’re looking at creating a suite of tools that are focussed on different aspects of cotton management, from insects to water to weeds whatever.

Reportedly, the Cotton Management Support Systems (CMSS) team was responsive to user feedback. User input directly influenced future development of the software. The software developer of the CMSS team articulated technical vision along with a comprehensive grasp of farming reality. In effect, linking cutting-edge technology such as GPS, GIS and DSS into CottonLOGIC was one approach proposed by users, yet the software developers were alert to the fact that a wholly integrated package may not overcome the difficulties. CottonLOGIC needed to be re-designed and re-developed as modules so that users could access the software components specific to their needs.

## 5 Discussion and Conclusion

IS is acknowledged to be a socio-technical discipline. In keeping with the view articulated by McKay et al (2005; 2007), the authors found that the ‘soft factors’ of technical artefact use, explored through the conceptual lens of a social science theory, impacted upon design, development, and incremental change. The human activities may not have been revealed in the absence of theory or by a more deterministic design science approach. This study is confirmation that a pluralist framework of both interpretivist and positivist persuasions “firmly positions design activity in IS in a socio-technical context ...” (McKay et al 2007, p.610). This paper corroborates Niehaves’ (2007, p.106) standpoint that design science research should be open to alternative epistemologies other than positivism for the descriptive evaluation of results since knowledge is never neutral nor complete. Bratteteig (2007, p.66) had a similar stance and stated “... if design includes the generation of ideas and the creation of alternative forms, design cannot be a scientific activity in line with the positivist epistemology”. Bratteteig (2007, p.66-67) explained, “designers aim to create usable artefacts ... users make sense of the design result”, therefore design and use are “important for both the design ideas ... and the evaluative side of creative activity”. As Hevner et al (2004, p.99) pointed out “the challenge for design science researchers in IS is to inform managers of the capabilities and impacts of new IT artefacts”.

Orlikowski and Barley (2001, p.149), in emphasising the mutual reciprocity between technology and human agents, claimed that “technologies are simultaneously social and physical artefacts” although, during integration into everyday practice, “users shape the implications of technologies” and the properties of technologies “influence agency”. While

the authors of this paper support the stronger focus on the IT artefact, as expounded by Orlikowski and Iacono (2001), the exclusion of the social appears detrimental to design science research.

In response to the queries posed by Niehaves (2007, p.101), “Is design science open to diverse epistemologies?” and “How does the discussion of design science relate to the discussion of epistemology, for instance positivism and interpretivism?”, the authors of this paper propose that design science research is diminished by the exclusion of the interpretive paradigm where data is gathered qualitatively from users for a rich understanding of the design, development and use of the technical artefact. Therefore, adoption of the multi-paradigmatic approach of IS means that social theories complement the constructivist and more positivist approaches of design science. As Avison et al (2001) urged, the social and human factors are at least as important as the technological ones.

## References

- Avison, D., Fitzgerald, G., and Powell, P. (2001). “Reflections on information systems practice, education and research: 10 years of the Information Systems Journal.” *Information Systems Journal*, 11, pp.3-22.,
- Banville, C., and Landry, M. (1989). “Can the Field of MIS be Disciplined?” *Communications of the ACM*, 32(1), pp.48-60.
- Bratteteig, T. (2007). "Design Science in Informatics." *Scandinavian Journal of Information Systems*, 19(2), pp.65-74.
- Giddens, A. (1984). *The Constitution of Society: Outline of the Theory of Structuration*, Berkeley and Los Angeles, University of California Press.
- Gregg, D., Kulkarni, U., and Vinze A. (2001) “Understanding the Philosophical Underpinnings of Software Engineering Research in Information Systems.” *Information Systems Frontier*, 3(2), pp.169-183.
- Gregor, S. (2006). "The Nature of Theory in Information Systems." *MIS Quarterly*, 30(3), pp.611-642.
- Gregor, S., Bunker, D., Cecez-Kecmanovic, D., Metcalfe, M., and Underwood, J. (2007). "Australian Eclecticism and Theorizing in Information Systems Research." *Scandinavian Journal of Information Systems*, 19(1), pp.11-38.
- Hevner, A., March, S., and Park, J. (2004). "Design Science in Information Systems Research." *MIS Quarterly*, 28(1), pp.75-105.
- Iivari, J. (2007). "A Paradigmatic Analysis of Information Systems as a Design Science." *Scandinavian Journal of Information Systems*, 19(2), pp.39-64.
- Mackrell, D., Kerr, D., and von Hellens, L. (2009). “A Qualitative Case Study of the Adoption and Use of an Agricultural Decision Support System in the Australian Cotton Industry: The socio-technical view”, *Decision Support Systems*, 47(2), pp.143-153.
- Mackrell, D., and Nielsen, S. (2007). “Structuration Theory in Information Systems Research: Relevance and Rigour from a Pluralist Research Approach.” *Proceedings of the 18th Australasian Conference on Information Systems (ACIS)*, 5-7 Dec 2007, Toowoomba, Australia.
- March, S., and Smith, G. (1995). "Design and Natural Science Research on Information Technology." *Decision Support Systems*, 15, pp.251-266.

- McKay, J., and Marshall, P. (2005). "A Review of Design Science in Information Systems." *Proceedings of the 16th Australasian Conference on Information Systems (ACIS)*, 29 Nov-2 Dec 2005, Sydney, Australia.
- McKay, J., and Marshall, P. (2007). "Science, Design, and Design Science: Seeking Clarity to Move Design Science Forward in Information Systems." *Proceedings of the 18th Australasian Conference on Information Systems (ACIS)*, 5-7 Dec 2007, Toowoomba, Australia.
- Niehaves, B. (2007). "On Epistemological Pluralism in Design Science." *Scandinavian Journal of Information Systems*, 19(2), pp.99-110.
- Orlikowski, W. (1992). "The Duality of Technology: Rethinking the Concept of Technology in Organisations." *Organization Science*, 3(3), pp.398-427.
- Orlikowski, W. (2000) "Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations." *Organization Science*, 11 (4), pp.404-428.
- Orlikowski W., and Barley, S. (2001). "Technology and Institutions: What can Research on Information Technology and Research on Organizations Learn from Each Other?" *MIS Quarterly* 25 (2), pp.145-165.
- Orlikowski, W., and Iacono, S. (2001). "Research Commentary: Desperately Seeking the "IT" in IT Research -- A Call to Theorising the IT Artifact." *Information Systems Research*, 12(2), pp.121-134.
- Orlikowski, W., and Robey, D. (1991). "Information Technology and the Structuring of Organizations." *Information Systems Research*, 2(2), pp.143-169.
- Patton, M. (2002). *Qualitative Research and Evaluation Methods*. Thousand Oaks, CA, Sage Publications.
- Popper, K., (1978). *Three Worlds, The Tanner Lectures on Human Values*, Delivered at the University of Michigan.
- Purao, S. (2002). *Design Research in the Technology of Information Systems: Truth or Dare*. Unpubl., School of Information Sciences and Technology, The Pennsylvania State University, University Park, State College, Pennsylvania.
- Rossi, M., and Sein, M. (2003). "Design Research Workshop: A Proactive Research Approach." *Proceedings of the 26<sup>th</sup> Information Systems Research Seminar (IRIS)*, 9-12 August 2003, Porvoo, Finland presentation slides available at <http://www.cis.gsu.edu/~emonod/epistemology/Sein%20and%20Rossi%20-%20design%20research%20-%20IRIS.pdf> (accessed 11 February 2009).
- Simon, H. (1996). *The Sciences of the Artificial*, Third Edition, Cambridge, MA, MIT Press.
- The Australian Cottongrower, (2006). *Cotton Yearbook 2006*, Toowoomba, Australia.
- Turban, E., Aronson, J., Liang, T., and Sharda, R. (2007). *Decision Support and Business Intelligence Systems*, 8th Edition, Prentice Hall, Upper Saddle River, NJ.
- Vaishnavi, V., and Kuechler, W. (2004, last updated June 29, 2007). "Design Research in Information Systems." from <http://www.isworld.org/Researchdesign/drisISworld.htm> (accessed 11 February 2009).
- Venable, J. (2006). "The Role of Theory and Theorising in Design Science Research." *Proceedings of the First International Conference on Design Science in Information Systems and Technology*, Claremont, CA.
- Walls, J., Widmeyer, G., and El Sawy, O. (1992). "Building an Information System Design Theory for Vigilant EIS." *Information Systems Research*, 3(1), pp.36-59.

Walsham, G. (1995). "Interpretative Case Studies in IS Research: nature and method." *Operational Research Society*, 4, pp.74-81.