A Paradigmatic Analysis of Information Systems As a Design Science

Juhani Iivari

Department of Information Processing Science, University of Oulu, Finland

juhani.iivari@oulu.fi

Abstract. The present essay discusses the ontology, epistemology, methodology and ethics of design science. It suggests that Information Systems as a design science should be based on a sound ontology, including an ontology of IT artifacts. In the case of epistemology, the essay emphasizes the irreducibility of the prescriptive knowledge of IT artifacts to theoretical descriptive knowledge. It also expresses a need for constructive research methods, which allow disciplined, rigorous and transparent building of IT artifacts as outcomes of design science research. The relationship between action research and design science research is also briefly discussed. In the case of ethics, the essay points out that Information Systems as design science cannot be value-free.

Keywords: information systems, design science, ontology, epistemology, methodology, ethics.

1 Introduction

Design science research has been practiced in Computer Science, Software Engineering and Information Systems for decades. Right from the beginning computer scientists have developed new architectures for computers, new programming languages, new compilers, new algorithms, new data and file structures, new data models, new database management systems, and so on. In short, they have been doing design science research all the time. Much of the early research in Information Systems (IS) was focused on systems development approaches and methods, e.g. the socio-technical approach (Bostrom and Heinen 1977; Mumford 1983), and the infological approach (Langefors 1966; Sundgren 1973; Lundeberg et al. 1978), representing design science research, too.

During the last 25 years, however, mainstream IS research has lost sight of its design science origin, because of the hegemony of the North-American business-school-oriented IS researchers over the leading IS publication outlets (such as MIS Quarterly, founded 1977; ICIS, started in 1980; and Information Systems Research, founded in 1991). The dominant research philosophy has been to develop cumulative, theory-based research to be able to make prescriptions. It seems that this 'theory-with-practical-implications' research strategy has seriously failed to produce results that are of real interest in practice. A pilot analysis of the practical recommendations made in articles in MISQ between 1996 and 2000 showed that these were weak (Iivari et al. 2004).

The current interest in design science (Nunamaker et al. 1990; 1991; Walls et al. 1992; March and Smith 1995; Hevner et al. 2004), may change the situation. It may again become legitimate to do design science research and to get it published in first-tier IS journals. But it is equally important that the above seminal papers have turned our attention to how to do design science research. One can expect that this will make future design science research more rigorous and researchers more reflective over the research process.

In my dissertation (Iivari 1983), which was essentially a piece of design science work, I characterized Information Systems (or Data Processing Science) as an applied science, and I was hardly the first to do so.[1] Nowadays this view is becoming widely accepted, even on the opposite side of the Atlantic, as evidenced by this quote from Benbasat and Zmud:

> our focus should be on how *to best design IT artifacts and IS systems* to increase their compatibility, usefulness, and ease of use or on how to best manage and support IT or IT-enabled business initiatives. (Benbasat and Zmud 2003, p. 191) [*italics* added by JI]

One can claim that design science has been implicit in this old conception of Information Systems as an applied science or discipline. When working on the idea of paradigms of IS development approaches or schools of thought (Iivari 1991), I was strongly influenced by my design science background.

Although I applied the framework of Burrell and Morgan (1979) as an analytical device, I expanded it in two respects. I included the ethics of research as an explicit analytical dimension and I incorporated constructive research to complement the nomothetic and idiographic research recognized by Burrell and Morgan (op.cit.). Both these extensions reflected my design science background.

The purpose of the present essay is to revisit the paradigmatic framework of Iivari (1991), applying it specifically to design science research. The framework distinguishes the ontology, epistemology, methodology and ethics of research. This essay suggests that Information Systems as a design science should be based on a sound ontology, and proposes the three worlds of Popper (1978) as a useful starting point for such an ontology. The paper suggests a three-level epistemology for Information Systems (conceptual knowledge, descriptive knowledge and prescriptive knowledge). It emphasizes the prescriptive knowledge of IT artifacts as a distinct knowledge area that cannot be reduced to descriptive knowledge. The essay expresses the need for constructive research methods, which allow the disciplined, rigorous and transparent building of IT artifacts as outcomes of design science research and make it possible to distinguish Information Systems as a design science from the practice of developing IT artifacts. The discussion on the relationship between action research and design science research emphasizes historical, practical, ontological, epistemological and methodological differences between the two research approaches. In the case of ethics, the essay points out that Information Systems as design science cannot be value-free and distinguishes three ethical positions for design science research: means-end oriented, interpretive and critical. The whole essay is summarized in twelve theses.

2 Ontology of Design Science

Design science research should be based on a sound ontology. Popper's (1978) three worlds provide a good starting point. World 1 is about material nature, World 2 about consciousness and mental states, and World 3 about products of human social action (Table 1). World 3 clearly includes human artifacts, and it also covers institutions and theories. Institutions are social constructions that have been objectified (Berger and Luckman 1967). While it is meaningful to speak about truth or 'truthlikeness' (Niiniluoto 1999) in the case of theories, it is not in the case of artifacts. Artifacts are only more or less useful for human purposes.[2]

The disciplines of computing are specifically interested in IT artifacts (Dahlbom 1996; Orlikowski and Iacono 2001; Benbasat and Zmud 2003). Dahlbom (1996) adopts a very broad and possibly confusing interpretation of the concept of artifact, claiming that "people and their lives are themselves artifacts, constructed, and the major material in that construction is technology" (p. 43). Referring more to IT, he continues:

> When we say we study artifacts, it is not computers or computer systems we mean, but information technology use, conceived as a complex and changing combine of people and technology. To think of this combine as an artifact means to approach it with a design attitude, asking questions like: Could this be different? What is wrong with it? How could it be improved? (p. 43).

He also claims that we should conceive of our discipline in terms of "using information technology" instead of "developing information systems" (p. 34).

World	*Explanation*	*Research phenomena*	*Examples*
World 1:	Nature	IT artifacts + World 1	Evaluation of IT artifacts against natural phenomena
World 2:	Consciousness and mental states	IT artifacts + World 2	Evaluation of IT artifacts against perceptions, consciousness and mental states
World 3:	Institutions	IT artifacts + World 3 Institutions	Evaluation of organizational information systems
	Theories	IT artifacts + World 3 Theories	New types of theories made possible by IT artifacts
	Artifacts • IT artifacts • IT applications • meta IT artifacts	IT artifacts + World 3 Artifacts	Evaluation of the performance of artifacts comprising embedded computing

Table 1: An ontology for design science

It was Orlikowski and Iacono (2001), however, who popularized the phrase 'IT artifact' within the IS research community. They define IT artifacts as "bundles of material and cultural properties packaged in some socially recognizable form such as hardware and/or software" (p. 121). Based on the 188 articles published in *Information Systems Research* in the decade beginning in 1990 and ending in 1999, they distinguish 13 views of IT artifacts. Most of these conceptualizations treat them as black boxes, without looking inside them. They simply focus on the computational capabilities of IT artifacts (the computational view of technology), their intended uses (the tool view of technology), technology as a variable (the proxy view of technology), how technologies come into being or how technologies come to be used (the ensemble view of technology).

It is my contention that Information Systems as a design science should be based on a sound typology of IT artifacts, and especially of IT applications. March and Smith (1995), echoed by Hevner et al. (2004), provide a classification of IT artifacts into constructs, models, methods and instantiations. In a way, this is a very general classification that can be applied to any IT systems. Unfortunately, its application is not always straightforward, since the classification so strongly reflects data/information modelling.

If we conceive of Information Systems as a design science that also builds IT artifacts, a natural question is what sort of artifacts we build, especially if we wish to distinguish Information Systems from Computer Science and Software Engineering. Research into the diffusion of innovations provides an initial typology of IT artifacts. Lyytinen and Rose (2003), refining Swanson (1994), distinguish base innovations, systems development innovations, and services. Services cover administrative process innovations (such as accounting systems), technological process innovations (such as MRP), technological service innovations (such as remote customer order entries) and technological integration innovations (such as EDI).

In my view the primary interest of Information Systems lies in IT applications. I propose a typology for IT applications which provides an alternative categorization of services to that in Lyytinen and Rose (2003). The typology distinguishes seven archetypes of IT applications (Table 2) based on the function/role the application serves.

Role/function	*Metaphors*	*Examples*
To automate	Processor	Many embedded systems Many transaction processing systems
To augment	Tool (proper)	Many personal productivity systems; Computer aided design
To mediate	Medium	E-mail, instant messaging, chat rooms, blogs Electronic storage systems (e.g. CDs and DVDs)
To informate	Information source	Information systems proper
To entertain	Game	Computer games
To artisticize	Piece of art	Computer art
To accompany	Pet	Digital (virtual and robotic) pets

Table 2: Archetypes of IT applications

The first four functions of Table 2 are close to ‘technology as a labour substitution tool’, ‘technology as a productivity tool’, ‘technology as a social relations tool’ and ‘technology as an information processing tool’ in the view of Orlikowksi and Iacono (2001). The roles ‘to automate’ and ‘to informate’ come from Zuboff (1988). Computer games illustrate the capability of IT applications to entertain. IT applications may also attempt to arouse artistic experience, and one can easily imagine a new sort of art that is essentially built on the interactive character of computer technology. Finally, IT artifacts such as digital pets can accompany human users.

To clarify Table 2, one should note that it interprets an information system proper as being a system whose purpose “is to supply its groups of users (...) with information about a set of topics to support their activities.” (Gustafsson et al., 1982, p.100). The definition implies that an information system is specific to the organizational (or inter-organizational) context in which it is implemented. Information content is also a central aspect of any information system to be designed.

The seven archetypes of IT applications are ideal types, and as such they may not occur in practice in their pure forms. A single application may include several functions. A word processor, for example, is primarily a tool intended to augment text production. At the same time it automates some aspects of text production (e.g. spelling). Zuboff (1988) claimed that to automate also allows one to informate. This can obviously be extended to cover other types of IT applications, so that computer games, for example, could at least in principle collect information about the users’ actions and reactions during playing which can be used to develop the game further. A second point is that many IT applications with the primary role of automating, augmenting, entertaining or possibly artisticizing may include an information system that supports the use of the primary functionality. E-mail, for example, with the original function of communicating messages, includes mailboxes that allow one to build a directory to informate about previous communications. Thus it can be developed into a fairly sophisticated information system about one’s electronically mediated social network and electronic communication within that network.

It is obvious that IT artifacts differ in design. A compiler design, for example, is quite different from the design of a specific information system, and design of an information system differs from game design. Swanson (1994) and Lyytinen and Rose (2003) suggest that IT artifacts differ in their diffusion, and it is my conjecture that IT application archetypes also differ in their acceptance, so that the Technology Acceptance Model (Davis et al. 1989; Venkatesh et al. 2003) is valid only in the case of some IT application artifacts.

Returning to Popper’s ontology, one should note that IT artifacts have increasingly invaded all spheres of the world (see Table 1). They may be embedded in natural objects of World 1, to measure physical states of objects, for example. Nanocomputing in particular is expected to open up totally new opportunities in this respect, since nanocomputers may be included in single cells of biological organisms, for example. How these IT artifacts affect natural phenomena is likely to become a significant research problem in the future. One can also deduce that IT artifacts have also invaded our consciousness and mental states, affecting our perceptions of the world, including the IT artifacts themselves. IT artifacts such as embedded computers are nowadays integral parts of other artifacts such as cars, TVs, phones, etc., and ubiquitous computing will intensify this. Information systems are significant constituents of institutions such as organizations and societies. The increasing capacity of computers has made it feasible to develop computationally more and more complex theories. One can also imagine that IT artifacts make it possible to develop totally new types of theories that cannot be represented using any other medium than computers, even though I do not have any specific examples in mind.

It is obvious that the research phenomena of Table 1 have an influence on the epistemology and methodology of Information Systems as a design science. For example, if an IT artifact is evaluated against natural phenomena of World 1 (e.g. how does the use of a mobile phone affect one's brain temperature?), against perceptions of World 2 (e.g. how does the use of a mobile phone affect one's perception of time and space?), against other artifacts (e.g. how does the use of mobile phones affect airplanes?), or against institutions of World 3 (e.g. how do mobile phones affect the nature of work in organizations), different facts and theories are involved, different research methods are applicable, and knowledge with different limits is achievable.

3 Epistemology of Design Science

Several proponents of design science suggest that it is associated with pragmatism as a philosophical orientation in its attempt to bridge science and practical action (March and Smith 1995; Hevner et al. 2004; Cole et al., 2005). In my view we should not conclude that design science necessarily implies the notion of truth from pragmatism as practical utility. To me, artifacts, if theories are excluded, do not have any truth value, and theories that describe and explain reality outside our mind have truth as correspondence (Niiniluoto, 1999). If practical action informed by a theory consistently proves to be successful, it provides additional evidence that there is at least a grain of truth in the theory (Bunge, 1967b).[3] In my dissertation (Iivari, 1983) I adapted Lehtovuori's (1973) framework from economics to structure IS research. Based on Chmielewicz (1970), Lehtovuori distinguishes four levels of research: the conceptual level, descriptive level (of economic theory), prescriptive level (of economic policy) and normative level (of economic philosophy).[4] The research goal at the conceptual level is essentialist: concepts and conceptual frameworks at this level aim at identifying essences in the research territory and their relationships. They do not have any truth value or truthlikeness, but they may be more or less useful when developing theories at the descriptive level (Bunge 1967a). The descriptive level aims at describing, understanding and explaining how things are. Following Törnebohm (1975), one can distinguish observational research, predictive research and explanatory research at the descriptive level. The prescriptive level is interested in how things could be and how to achieve the specified ends in an effective manner. It produces alternative 'methods' (or means) to achieve certain utilitarian ends. It may be that today I would call these 'methods' artifacts, even though not all 'methods' need be artifacts.[5] Artifacts and recommendations as such do not have a truth

Type of knowledge	*Illustrations*
Conceptual knowledge (no truth value) • concepts, constructs • classifications, taxonomies, typologies, • conceptual frameworks	$c_1, c_2, \ldots c_n$, $C_1, C_2, \ldots C_n$ $U = C_1 \cup \ldots \cup C_n$; $C_i \cap C_j = \emptyset$, $i \neq j$ Systems concepts, ontologies, etc.
Descriptive knowledge (truth value) • observational facts • empirical regularities } • theories and hypotheses } causal laws (Niiniluoto 1993)	• X causes A in situation B • X tends to cause A in situation B with probability p
Prescriptive knowledge (no truth value) Design product knowledge	The artifact: • idea, concept, style • functionality, behaviour • architecture, structure • possible instantiation
Design process knowledge: Technological rules (Bunge 1967b)	In order to achieve A • do $(act_1, act_2, \ldots, act_n)$
Technical norms (Niiniluoto 1993)	If you want A, and you believe that you are in a situation B, then • you should do X • it is rational for you to do X • it is profitable for you to do X

Table 3: Epistemology of design science

or truth-like value, but only statements about their efficiency and effectiveness have such a value.

This three-level structure can be used to structure knowledge produced by IS research (Table 3). Conceptual knowledge includes concepts, both singular (c_i) and more general class concepts (C_j), classifications, taxonomies, typologies, clusters, etc. (Bailey 1994; Bunge 1967a; Doty and Glick 1994) and more general conceptual frameworks such as the infological concepts of Langefors (1966), the Bunge-Wand-Weber ontology (Wand and Weber, 1990) and classifications of IT innovations (Swanson 1994; Lyytinen and Rose 2003), to mention just a few. As these examples illustrate, much of the knowledge produced by IS research is conceptual by nature.

Observational facts such as who invented what and when, Moore's Law and the Technology Acceptance Model (Davis et al. 1989) illustrate descriptive knowledge. Empirical regularities and explanatory theories allow one to identify causal laws (Niiniluoto 1993) either deterministic ('X causes A in situation B') or probabilistic ('X tends to cause A in situation B with probability p').

Relatively speaking, prescriptive knowledge is the least well understood form of knowledge in Table 3. The distinction between design product knowledge and design process knowledge is borrowed from Walls et al. (1992). Design product knowledge in particular seems to be missing from philosophical treatments such as Bunge (1967b) and Niiniluoto (1993). The three aspects of design product knowledge In Table 3 are close to the three criteria of artifacts identified by Beckman (2002): intentional, operational and structural. Beckman illustrates these in the case of 'knifehood'. The intentional criterion implies that a thing is a knife because it is used as a knife. The operational criterion means that a thing is a knife because it works like a knife. The structural criterion suggests that a thing is a knife because it has the shape and fabric of a knife. Beckman (2002) also includes a fourth criterion, the conventional one. It implies that a thing is a knife because it fits the reference of the common concept of 'knife. In the design science research context the conventional criterion is a significant goal in the sense that the artifact (e.g. a new systems development method OO+++) will be accepted as a valid instance of some class concept (e.g. object-oriented methods) by a relevant community (e.g. by practitioners). Despite this, I do not think that it is an inherent aspect of the artifact, since the artifact may achieve general community acceptance years after its invention and construction. Therefore the conventional criterion is not explicitly in Table 3, but it in a way the criterion is covered at the conceptual level (type or class of a meta-artifact). Following March and Smith (1995) I have added possible instantiation as a fouth aspect.

Bunge (1967b) identifies technological rules as central constituents of knowledge in applied sciences. A technological rule is a sequence of acts that prescribe how one should proceed in order to achieve a predetermined goal. While simplistic in its sequential nature, it can be considered a ‘prototype’ of design process knowledge. Although one might interpret a technological rule as covering how to construct a design product, it only very implicitly includes knowledge of the design product. One should also note that a technological rule in itself is an artifact. If a technological rule describes how to build a complex artifact, it is in itself probably fairly complex as an artifact, too. Bunge (1967b) does not address the question of how to build technological rules as artifacts.

Niiniluoto (1993) suggests that the old dichotomy between basic research and applied research should be replaced by a distinction between descriptive science and design science, based on different knowledge claims. While the typical knowledge claims of descriptive science are deterministic or probabilistic causal laws, design science comprises technical norms, as illustrated in Table 3. Technical norms link recommendations at the prescriptive level to causal laws at the descriptive level. One should note from the design science viewpoint, however, that Niiniluoto is silent about design products (denoted by X in Table 3). Although he gives some examples of X such as medical treatments, fertilizers, materials used in airplanes, etc., he fails to recognize design product knowledge as a separate category of knowledge in design science.

Niiniluoto’s technical norms give an impression that design science knowledge (technical norms) is largely reducible to descriptive knowledge (causal laws). The relationship between science and technology has been of considerable interest (Gardner 1994; 1995), leading to the conclusion that descriptive science and technology are separate, even though mutually interacting, bodies of thought (Layton 1974). This seems to be so especially in Information Systems, where IT artifacts seem to be relatively independent of descriptive theories concerning technology, human beings, organizations and other institutions. Even though technical implementability is a significant issue, the dependence of IT artifacts on the laws of nature is mainly latent, and IS designers do not need to constantly consider them. One can expect that the need for theories of human beings is the most obvious in the context of human-computer-interaction (HCI). However, the theoretical foundation of HCI is unclear and fragmented (Clemmensen 2006). It is also uncertain to what extent existing theories inform the HCI design either directly or indirectly through design methods, standards, guidelines, etc.

The situation in Information Systems is very similar. It has diversity of reference disciplines from which it has adopted a number of theories (Benbasat and Weber 1996; Hirschheim and Klein 2003), but these theories are weakly linked to IT artifacts and their design. Despite this weak reliance on descriptive theories people design reasonably successful IT artifacts. This makes one to wonder whether the IS research community tends to exaggerate to the significance of descriptive theoretical knowledge for prescriptive knowledge of how to design IT successful artifacts. In conclusion, in line with Layton (1974) I am inclined to suggest that prescriptive knowledge forms a knowledge realm of its own and is not reducible to descriptive knowledge.

It was Walls et al. (1992) who pioneered the idea in Information Systems that design science should be rooted in theories. They suggested that an "IS design theory' for a product should consist of meta-requirements (the class of goals to which the theory applies), meta-design (the class of artifacts hypothesized to meet the meta-requirements), kernel theories (theories from the natural and social sciences governing design) and testable design product hypotheses (used to test whether the meta-design satisfies the meta-requirements). An IS design theory for a process would comprise a design method (a description of the procedures for artifact construction), kernel theories and testable design process hypotheses (used to verify whether the design method results in an artifact which is consistent with the meta-design).

Even though I am afraid that the strong theory orientation[6] of the leading IS journals may exaggerate the dependence of prescriptive knowledge on descriptive knowledge, I would consider the existence of a kernel theory to be a defining characteristic of a 'design theory'. As a consequence, I claim that without a sound kernel theory it is not justified to speak about 'design theory'. This is quite an ambitious requirement, because it is difficult, as Walls et al. (1992) demonstrate, to find convincing examples of IT meta-artifacts with well-defined kernel theories. As a result there seems to be some tendency to soften the requirements for a kernel theory. Markus et al. (2002), for example, allow any practitioner theory-in-use to serve as a kernel theory. This implies that a design theory is not necessarily based on any scientifically validated knowledge. Taking a cynical viewpoint, if kernel theory is forgotten, there is a danger that the idea of a 'design theory' will be (mis)used just to make our field sound more scientific without any serious attempt to strengthen the scientific foundation of the meta-artifacts proposed.[7]

The hierarchy of Table 3 can easily be mapped to the types of 'theories' suggested by Gregor (2006). 'Theories for analyzing and predicting' lie at then conceptual level. 'Theories for predicting' are empirical regularities. 'Theories for explaing and predicting' refer to theories at the decriptive level. 'Theories for design and action' are at the prescriptive level. Only 'theories of explaining' when interpreted in terms of grand theories such as Critical Social Theory, Structuration Theory, Actor-Network Theory, Activity Theory, etc. do not have any correspondent in Table 3. Therefore, a fuller discussion of knowledge at different levels is provided by in Gregor (2006).

4 Methodology of Design Science

As pointed out in the Introduction, much research in Computer Science and Software Engineering in particular has consisted of constructing artifacts. Recognizing this, I suggested 'constructive research' to denote the specific research methods required for constructing artifacts (Iivari 1991). Well-known classifications of IS research methods such as those of Benbasat (1985), Jenkins (1985) and Galliers and Land (1987) do not recognize anything resembling constructive research methods, nor, even, does a recent review of research methods in the IS literature (Chen and Hirschheim 2004).

It is widely understood that building artifacts in design science research is at least ideally creative (Nunamaker et al. 1990-1991; March and Smith 1995; Hevner et al. 2004). One could maintain that it has a lot in common with theory building, which has been of considerable interest in the methodology of science (e.g. Dubin 1969). One can speculate, however, that artifacts in particular leave much more space for creative imagination, since they are not assumed to describe or explain any existing reality. IT artifacts may create their own virtual world (e.g., computer games, computer art and computer pets) where the laws of nature, for example, are not valid. Because of the creative element, it is difficult to define an appropriate method for the design science activity of artifact building.

Despite the above difficulty, I see the existence of constructive research methods as highly essential for the identity for Information Systems as a design science. It is the rigor of constructing IT artifacts that distinguishes Information Systems as design science from the practice of building IT artifacts. One should note here that the construction of innovative IT artifacts (or IT meta-artifacts) is not a monopoly of the research community, but practitioners may also do it. Acknowledging this, there are two options to demarcate Information Systems as design science from inventions by practitioners. The first is to accept that there is no constructive research method that distinguishes the two, but that the difference lies in the evaluation: the essence of Information Systems as design science lies in the scientific evaluation of artifacts. This is one option, but it easily leads to reactive research in which Information Systems as a design science focuses on the evaluation of existing IT artifacts rather than on the building of new ones.

The second option is to try to specify a reasonably rigorous constructive research method for building IT artifacts. It would be this method that differentiates the design science construction of IT artifacts from the Gyro Gearloose style of invention in practice.[8] If a practitioner applies the same rigor as an IS researcher, he/she is essentially a researcher. I would expect that this would make Information Systems as a design science more proactive, attempting to lead the evolution of IT and not merely react to it.

I did not detail the method of constructive research in any way in Iivari (1991), but at about the same time Nunamaker et al. (1990-1991) proposed that systems development could serve as a specific research method for constructing artifacts. They introduced a model of four interacting research activities, theory building, experimentation, observation and systems development, where systems development lies at the centre. The process that they propose for systems development is quite a conventional software development model. In as far as the artifacts to be built are systems, systems development is a natural candidate for methods of constructive research. The method seems particularly relevant when the purpose is to prove the concept by implementing (instantiating) the system. One should note, however, that not all artifacts developed in design science research within Computer Science, Information Systems and Software Engineering are information or software systems (e.g. systems development methods), and it is an open question to what extent systems development methods work as research methods. If systems development methods really are applicable in, this should put an end to the regression of meta-levels between artifacts, as systems development methods as meta-artifacts for the IS development process could be employed for developing other meta-artifacts.

If we consider some pitfalls of the idea of systems development as a method of constructive research, the first question is whether systems development methods allow sufficient room for the creativity and serendipity that are essential for innovation. This is always a significant concern when attempting to make the building process more disciplined, rigorous and transparent.

Perhaps the most serious weakness of the model of Nunamaker et al. (1990-1991) is that it integrates systems development quite weakly with other research activities, i.e. theory building, experimentation and observation. Their process model for systems development research consists of five stages: construct a conceptual framework, develop a system architecture, analyse and design the system, build the (prototype) system and observe and evaluate the system. Only the first and the last stages of this process model are related to other research activities, and the first stage only advises one to study relevant disciplines for new approaches and ideas.

Hevner et al. (2004) propose that the rigor of design science research is derived from the effective use of *prior* research (existing knowledge base). I would claim that the construction process should be made as transparent as possible if it is to be considered a design science activity. It is not enough for the artifact just to come out of the blue. I suggest four major sources of ideas for design science research to make the origin more transparent:

1. Practical problems and opportunities
2. Existing artifacts
3. Analogies and metaphors
4. Theories

The first of these emphasizes the practical relevance of research. Furthermore, it is well-known in innovation diffusion research (Rogers 1995) that customers serve as a significant source of innovations (von Hippel 1988), epcially of IT innovations (von Hippel 2005). I do not claim that researchers should attempt to solve practical problems exactly as they appear in practice. A practical problem may be a conglomerate of different problems, and a piece of research may not attempt to address the whole conglomerate but may focus only on some specific subproblem. A practical problem may also be abstracted to make it more general and easier to link to theories. One should note, however, that design science is also about potentiality. A new idea or artifact may provide totally new opportunities to improve practice long before practitioners recognize any problem. Many significant innovations in our field, such as the relational data model and the first ideas of object-orientation, illustrate this.

Yet most design science research consists of incremental improvements to existing artifacts, as illustrated by research into conceptual information modelling in the 1970's and into object-oriented systems development in the 1990's. Typically, the marginal value of additional improvements decreases until the research gradually fades out.[9] An understanding of existing comparable artifacts is essential in design science research, however, since the novelty and contribution of new artifacts must be evaluated in the light of the existing ones.

It is also well-known that analogies and metaphors stimulate creativity (Couger et al. 1993). In the case of IT artifacts, for instance, cognitive and biological theories have provided useful metaphors for computing, such as neural networks and genetic algorithms. The desktop metaphor led to the graphical user interfaces which are dominant nowadays. The spreadsheet metaphor led to spreadsheet software, which forms one of the most widely applied personal productivity tools.

As discussed above, Walls et al. (1992) pioneered the idea that design science should be based on kernel theories. Ideally, kernel theories should serve as sources of ideas in design science research, but as pointed out above, the IS research community may exaggerate the significance of kernel theories as sources of new IT innovations.

Many authors associate design science with action research (Burstein and Gregor 1999; Järvinen 2001; Cole et al. 2005; Järvinen 2007). This is understandable, since both attempt to change the world. Yet I wish to emphasize that they are historically, practically, ontologically, epistemologically and methodologically quite different and that in my view they should be kept conceptually clearly separate. As is well-known, action research has its roots in Kurt Lewin and the socio-technical design movement (Baskerville and Myers 2004), whereas design science research has its roots in engineering. In terms of van Aken (2004), action research has addressed more improvement problems than construction problems. It has been much more focused on 'treating social illnesses' in organizations and other institutions. Technology change may be part of that 'treatment', but the focus has been more on adopting technology than building it. Design science research, especially in engineering and medicine, has focused on the construction of artifacts, most of them having material embodiment.[10] Even though it may be informed by practical problems, design science research, both the construction of new artifacts and their initial evaluation (testing), is usually done in laboratories that are clearly separated from potential clients.

Most design science research in engineering and medicine, for example, adopts a realistic or materialistic ontology, whereas action research at least accepts a more nominalistic, idealistic and constructivist ontology (Burrell and Morgan 1979; Iivari et al. 1998; Niiniluoto 1999). As Niiniluoto (1999) points out, materialism attaches primacy to World 1 in Popper's classification and idealism to World 2. Action research, however, is interested in institutions of World 3, which is socially constructed. As a consequence, design science research, especially in engineering and medicine, has reflected a positivistic epistemology (Burrell and Morgan 1979) both in terms of knowledge applied from reference disciplines (such as physics, chemistry and biology) and knowledge produced (design product knowledge, technical norms and technological rules), whereas action research is very strongly based on an anti-positivistic epistemology. Actually, one can claim that the very idea of action research is anti-positivistic in its epistemology. Each client organization is unique, with its own problems, and therefore one cannot treat all organizations using the same medication.

As a consequence, my conclusion is just the opposite to that of Cole et al. (2005), who maintain that design science and action research share important assumptions regarding ontology and epistemology.

One explanation for this discrepancy may be that Cole et al. (2005) implicitly limit design science to information systems in an organizational context. One can question if the ontology and epistemology of design science research might be different, when it specifically focuses on IT artifacts to be used in institutional organizational contexts in World 3. Based on my own work on paradigmatic assumptions regarding systems development approaches (Iivari, 1991; Iivari, 1998), I am doubtful. It was found that all seven IS development approaches (or schools of thought) analysed in Iivari (1991) shared a fairly realistic ontology and positivistic epistemology, whereas Iivari et al. (1998) deliberately focused on five IS development approaches that contrasted with the paradigmatic assumptions identified in Iivari (1991). These examples illustrate that instances of design science research constructing quite comparable IT artifacts may differ in their ontological and epistemological assumptions.

Despite the differences between design science and action research, I do not claim that they are mutually exclusive. Action research may well be used to evaluate artifacts developed in design science, and it may also provide information on how to improve those artifacts. We have ample examples of the application of such action research in the context of the developing of IS development methods (ETHICS and ISAC, for example).[11] My claim is, however, that artifacts developed in design science should first be tested in laboratory and experimental situations as far as possible. One should not start with testing in the real situations, except perhaps in very exceptional, special situations.

5 The Ethics of Design Science

Design science research in itself implies an ethical change from describing and explaining of the existing world to shaping it. The ethics of research concern the responsibility of a scientist for the consequences of his research and its results. Even though it may be questionable whether any research can be value-free, it is absolutely clear that design science research cannot be. Consequently, the basic values of research should be expressed as explicitly as possible.

Adapting Chua (1986), Iivari (1991) distinguishes three potential roles for Information Systems as an applied discipline: 1) means-end oriented, 2) interpretive, and 3) critical. In the first case the scientist aims at providing means knowledge for achieving given ends (goals), without questioning the legitimacy of those ends. According to Chua (1986), the aim of an “interpretivist scientist is to enrich people's understanding of their action", "how social order is produced and reproduced" (p. 615). The goals (ends) of action are often not so clear, and one should also focus on unintended consequences. A critical scientist sees that research has "a critical imperative: the identification and removal of domination and ideological practice" (p. 622). Goals (ends) can be subjected to critical analysis.[12]

Much design science research is naturally means-end oriented. This concerns especially constructive research involved with the building of artifacts. But constructive research can also be critical, as exemplified by the Scandinavian trade-unionist systems development approach (Bjerknes et al., 1987). Evaluation studies can be means-end oriented, interpretive and/or critical, where a means-end oriented evaluation is only interested in how effectively the artifact helps achieve the given goals or ends, an interpretive piece of evaluation research may attempt to achieve a rich understanding of how an IT artifact is really appropriated and used and what its effects are, without confining the focus on the given ends of its initial construction, and a critical study is interested in how an IT artifact enforces or removes unjustified domination or ideological practices.

More concretely, one can also question the values of IS research, i.e. whose values and what values dominate it, emphasizing that research may openly or latently serve the interests of particular dominant groups. The interests served may be those of the host organization as perceived by its top management, those of IS users, those of IS professionals or potentially those of other stakeholder groups in society.

6 Summary

The ideas put forward here can be summarized in the following twelve theses:

1. Information Systems is ultimately an applied discipline.
2. Prescriptive research is an essential part of Information Systems as an applied discipline.
3. The design science activity of building IT artifacts is an important part of prescriptive research in Information Systems.
4. The primary interest of Information Systems lies in IT applications and therefore Information Systems as a design science should be based on a sound ontology of IT artifacts and especially of IT applications.
5. Information Systems as a design science builds IT meta-artifacts that support the development of concrete IT applications.

6. The resulting IT meta-artifacts essentially entail design product and design process knowledge.
7. Design product and design process knowledge, as prescriptive knowledge, forms a knowledge area of its own and cannot be reduced to the descriptive knowledge of theories and empirical regularities.
8. Constructive research methods should make the process of building IT meta-artifacts disciplined, rigorous and transparent.
9. Explication of the practical problems to be solved, the existing artifacts to be improved, the analogies and metaphors to be used, and/or the kernel theories to be applied is significant in making the building process disciplined, rigorous and transparent.
10. The term 'design theory' should be used only when it is based on a sound kernel theory.
11. Information Systems as a design science cannot be value-free, but it may reflect means-end, interpretive or critical orientation.
12. The values of design science research should be made as explicit as possible.

The first thesis attempts to strengthen the practical orientation of Information Systems by reminding us that, as an applied discipline, it is interested in how to change the world, and not only how the world is. This does not mean that IS research comprises only 'applied research', even though prescriptive research is essential to Information Systems (Thesis 2). Prescriptive research should not confined only to practical implications of descriptive theories (Benbasat and Zmud 2003), but comprises design science research of building IT artifacts (Thesis 3).

The present essay suggests the three worlds of Popper (1978) as a general ontology for design sciences. Thesis 4 expresses the need for a special World 3 ontology for IT applications. In line with Walls et al. (1992), Thesis 5 reminds us that Information Systems as a design science attempts to build IT meta-artifacts rather than concrete IT applications. Thesis 6 points out that these IT meta-artifacts are essentially knowledge (Hevner et al. 2004), while Thesis 7 underlines the fact that prescriptive knowledge and descriptive knowledge are distinct realms of knowledge and that the former cannot be reduced to the latter. The current 'obsession' of leading IS journals (such as MIS Quarterly and Information Systems Research) with theory may by dysfunctional from the viewpoint of design science if it is required that all contributions of design science research must have a strong grounding in theory (see footnote 12).

Recognizing that the question of how to build IT artifacts in design science research (Hevner et al. 2003) is relatively poorly understood, Thesis 8 expresses the need for disciplined, rigorous and transparent constructive research methods. It is this methodological rigor that distinguishes Information Systems as design science from the practice of building of IT artifacts. Thesis 9 suggests that the building process may be based on practical problems, existing artifacts to be improved, analogies and metaphors, and/or kernel theories, allowing, by contrast with Walls et al. (1992), that IT meta-artifacts are necessarily to be based on kernel theories. Thesis 10 attempts to prevent any artificial 'theoretization' of design science by suggesting that if an IT meta-artifact is not based on any sound kernel theory, one should not call it 'design theory' (Gregor 2006).

The final two theses emphasize the significance of values in design science research, claiming that they should be as explicit as possible.

Notes

1. I recognize that the term 'applied science' is problematic. First, there is considerable controversy over whether it is appropriate to make a distinction between pure/basic science/research and applied science/research (see Niiniluoto, 1993). Second, there is also a controversy over whether technology is just applied science and technological knowledge reducible to applied science (Gardner 1994, 1995). Despite these problems, I find the distinction between 'pure' and 'applied' useful in the case of disciplines. A pure discipline is primarily interested in how the world is, whereas an applied discipline is interested in how to change the world. Note that this does not mean that an applied discipline such as Information Systems should include only 'applied research'.
2. The stimulating article by Beckman (2002) suggests a more refined ontology of artifacts which distinguishes four worlds: The realm of physics, the realm of biology, the realm of mind, and the realm of artifacts.
3. The Manhattan project for developing the first atomic bomb was one of the biggest design science research projects in the history of the humankind. The project was successful in the sense that it managed to build the bomb, but what was the utility of that project? To whom? It demonstrated, however, that the physical theory behind the atomic bomb (nuclear fission) was valid.
4. I dropped the normative level of the original framework of Chmielewicz (1970) and Lehtovuori (1973). The level of economic philosophy has a normative research goal concerned with values, which according to Lehtovuori (1973) do not have any truth value. It is still a controversial question whether one can make 'ought-to' conclusions based on 'what is'.
5. At the time of my dissertation I was not aware of true nature of the book by Herbert Simon on "The Science of the Artificial" (1969). I thought that was about Artificial Intelligence, and thus overlooked it.

6. The editorial policy of MIS Quarterly requires that submissions to its research article department “have a strong grounding in theory, whether it is a new theory the authors are advancing or an existing theory the authors are testing, refining, or challenging” (http://www.misq.org/roadmap/standards.html, accessed 2.12.2006). Similarly, the editorial policy of Information Systems Research expects that research article submissions “should have a strong grounding in theory. Such a theory could either be a new theory that the authors are advancing or an existing theory the authors are illustrating, testing, refining, challenging, or simply applying.” (http://iol-a.informs.org/site/ISR/index.php?c=11&kat=Submission+Guidelines, accessed 2.12.2006).
7. In fact, Walls at al. (1992) fall into this trap. They suggest that the information systems development life-cycle is a design theory, although I am not aware of any kernel theory on which it is based.
8. Gyro Gearloose is a fictional character created by Carl Barks for the Walt Disney company. The purpose of using this figure to symbolize inventors in the field is not to ridicule them, but quite the contrary.
9. One can, of course, observe a similar phenomenon in descriptive research, as illustrated by the extensions of the Technology Acceptance Model (Davis et al., 1989).
10. In the case of medicine design science research refers to the development of new drugs and treatments.
11. Recognizing the nature of systems development methods and approaches as ‘ways of thinking’, ‘ways of control’, ‘ways of modeling’, ‘ways of working’ and ‘ways of support’ (ter Hofstede and van der Weide, 1992), one can claim that a research approach that combines design science research and action research is particularly appropriate when developing systems development methods. Even in this case I am not sure that the systems development method should primarily be constructed in an action research context. Action research may be used in the evaluation (testing) and refinement of the method.
12. Note that Iivari (1991) applied the above distinction as an ethical dimension, whereas Orlikowski and Baroudi (1991) applied a very similar distinction as an epistemological dimension. The critical perspective clearly illustrates the problem with the epistemological dimension. Critical research may apply either a positivistic or an anti-positivistic epistemology.

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