Chapter 1
Introduction to Design Science Research

> *"In the same way that industrial designers have shaped our everyday life through objects that they design for our offices and for our homes, software interaction design is shaping our life with interactive technologies – computers, telecommunications, mobile phones and virtual worlds. If I were to sum up this in one sentence, I would say that it's about shaping our everyday life through digital artifacts – for work, for play, and for entertainment."*
>
> –Gillian Crampton Smith (Moggridge 2007)

Since the dawn of the digital revolution, information technologies have changed the way we live, work, play, and entertain. Designers of IT-based digital technology products play a critical role in ensuring that their designed artifacts are not just beautiful but provide value to their users. Users are increasingly interacting with a digital world. Designing interactions in this new world is a challenging task. The experiences we have when we browse the web, or visit amazon.com, sell/buy stuff on eBay or play amusing games on our mobile cell phones do have a tremendous impact on how we live our lives. Designing information systems is even more challenging.

1.1 What Is Design? – Different Perspectives

You know when you see a good design but it is often hard to define it. Charles Eames offered the following: "A plan for arranging elements in such a way as to best accomplish a particular purpose." Design is the instructions based on knowledge that turns things into value that people use. It embodies the instruction for making the things. However, design is not the thing. For example, we can say that source code is design while compiled code is the thing itself.

A number of disciplines have all made design a central element in what they do. This includes architecture, engineering, computer science, software engineering,

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media, and art design and information systems. They all have slightly different views on what they call design.

Engineering design is the systematic intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints (Dym and Little 2000).

Software (engineering) design is a "thing" as well as a "process" which is conscious, keeps human concerns in the center, is a conversation with materials, is creative, has social consequences, and is a social activity (Winograd 1996).

When it comes to design, we are best familiar with beautiful architectures that capture our imagination. Mitch Kapor actually wrote that good software should be like well-designed buildings. They exhibit three characteristics:

- *Firmness*: A program should not have any bugs that inhibit its function.
- *Commodity*: A program should be suitable for the purposes for which it was intended.
- *Delight*: The experience of using the program should be a pleasurable one.

Our interest in this book is to understand design and its role in both the academic discipline and practice we call the information systems. Design in information systems is both an iterative process (set of activities) and a resulting product (artifact) – a verb and a noun (Walls et al. 1992). Very simply stated, design in information systems deals with building software artifacts which solve a human problem. The designed artifact must be evaluated to show that not only does it solve the problem but also does it in an efficient manner by providing utility to its user. But how does one conduct design research? Is design a research methodology? Is design even a scientific paradigm?

1.2 What Is Research?

To explain fully what is research or how to do research is beyond the scope of this book. However, the thesis we are explaining is a type of research method we call design science research. Hence in that context, it is important to know a little bit about research.

Research can be very generally defined as an activity that contributes to the *understanding* of a *phenomenon* (Kuhn 1970; Lakatos 1978). *Phenomenon* is typically a set of behaviors of some entity that is found *interesting* by the researcher or by a group – a research community. *Understanding* is knowledge that allows prediction of the behavior of some aspects of the phenomenon. Everywhere, our knowledge is incomplete and problems are waiting to be solved. We address the void in our knowledge and those unresolved problems by asking relevant questions and seeking answers to them. The role of research is to provide a method for obtaining those answers by inquiringly studying the evidence within the parameters of the scientific method.

Research is a process through which we attempt to achieve systematically and with the support of data the answer to a question, the resolution of a problem, or a greater understanding of a phenomenon. This process, frequently called *research methodology*, has eight distinct characteristics:

- Research originates with a question or problem
- Research requires a clear articulation of a goal
- Research follows a specific plan of procedure
- Research usually divides the principal problem into more manageable subproblems
- Research is guided by the specific research problem, question, or hypothesis
- Research accepts certain critical assumptions
- Research requires collection and interpretation of data or creation of artifacts
- Research is by its nature cyclical, iterative, or more exactly helical

1.3 Is Design a Science?

There is considerable debate in the community whether design is a science or a practice. What constitutes a science is a big question that is perhaps outside the scope of this book. But we would like to understand the elements of how science is structured? Vannevar Bush (1945) had said that science has two end points on a scale: *Basic* fundamental research (typically funded by federal agencies such as NSF) and *applied* research (typically funded by corporations). Any science develops and evolves over time and proceeds through various stages. A useful tool that is often used to analyze the development of science is the Stokes matrix (see Fig. 1.1).

Science can be structured in two axes. On the vertical axis, it represents how fundamental the knowledge is. On the horizontal axis, it represents how useful that

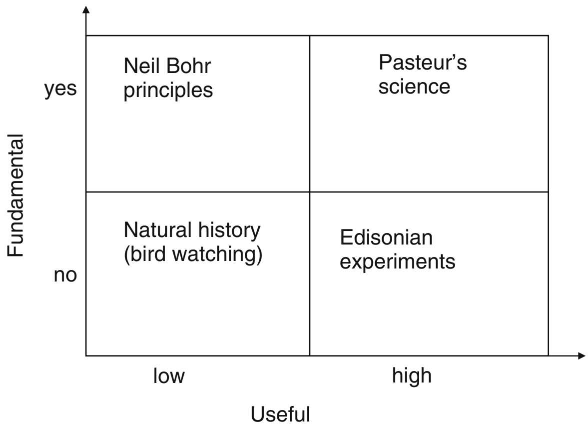


Fig. 1.1 The Stokes matrix quadrants

knowledge is to solve everyday problems. Most science begins at the lower left quadrant referred to as "natural history." This is similar to bird watching, where scientists observe what is happening. Then they capture that basic observation and codify it as knowledge. We do not understand fully why things behave the way they do but we can describe what we see. This is an important quadrant and with respect to design, we have a lot of captured tacit and codified knowledge of design, design process, and product outputs. But note that this knowledge is rather of low usefulness.

The lower right corner represents the "Edisonian experiments" quadrant where the knowledge is not that fundamental but experiments are proving to be quite useful. Hands-on experiments and playing with design are critical in this phase. It is more useful when you actually build designs. The "Neil's Bohr" quadrant on the upper left corner is when science becomes more fundamental but its usefulness is still restricted. We think that the present understanding of design science research is currently located at this quadrant (in the present moment). Lots of the pioneering work done by Herb Simon, Chris Alexander, Fred Brooks, David Parnas, and others belong here. This is fundamental knowledge that designers can put to use. The upper right quadrant termed "Pasteur's quadrant" is where we would like to go: fundamental design knowledge that is extremely useful. That is where a science of design will emerge. Carliss Baldwin at a recent keynote talk at an NSF workshop summarized it well:

> There are theories and design principles in individual design domains such as architecture, engineering design, and software engineering. But a science of design will not emerge from core domains. It has to come from an overarching disciplinary scientific field. The science of design and its theories should be generalizable and applicable across a wide variety of domains and specialties (NSF 2007, PI Workshop on Science of Design, Arlington, Virginia).

In the context of the present discussions, one can ponder on what is good science? It is widely accepted that the basic goal of good science is to develop a theory, paradigm, or model that provides a basis for research to understand the phenomenon being studied. This model is useful only in so far as it helps to explain the observations. To this end, science develops by a formal procedure, usually termed "the scientific method."

In a brilliant essay, Kirschenmann (2002) laments on how traditional scientific economy of prestige and the generous funding that follows it has distorted the entire "scientific process" which was once a "purely academic pursuit" but has now "been commercialized to an astonishing degree by researchers themselves." How has this happened? Evelyn Fox Keller posits "Scientists, she says, "are language-speaking actors" and "the words they use play a crucial role in motivating them to act, in directing their attention, in framing their questions, and in guiding their experimental efforts." Today we are in a world where we do not see science that questions established dogmas but rather science that is directed by commercial and monetary interests.

1.4 What Is Design Science Research?

Based on the notions and discussions above, we can now define design science research (DSR) as follows:

> Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem.

We hereby lay down the first principle of DSR:

> *The fundamental principle of design science research is that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact.*

1.5 Placing DSR in Context

Our community of practice is information technology and information systems. Information is "data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective actions or decisions." Technology has been defined as "practical implementations of intelligence." Technology is practical, or useful, rather than being an end in itself. It is embodied, as in implementations or artifacts, rather than being solely conceptual (March and Smith 1995; Hevner et al. 2004). Technology includes the many tools, techniques, materials, and sources of power that humans have developed to achieve their goals. Technologies are often developed in response to specific task requirements using practical reasoning and experiential knowledge. IT then is technology used to acquire and process information in support of human purposes. It is typically instantiated as IT systems – complex organizations of hardware, software, procedures, data, and people, developed to address tasks faced by individuals and groups, typically within some organizational setting.

IS is a unique discipline concerned with how IT intersects with organizations and how it is managed. IS research to date has produced knowledge by two complementary but distinct paradigms, *behavioral sciences* and *design sciences* (Hevner et al. 2004). Behavioral science which draws its origins from natural science paradigm seeks to find the truth. It starts with a hypothesis, then researchers collect data, and either prove or disprove the hypothesis. Eventually a theory develops. Design science on the other hand is fundamentally a problem-solving paradigm whose end goal is to produce an artifact which must be built and then evaluated. Working with the technology and going through the process of construction and understanding the salient issues with the artifact is central to this paradigm. Architects, engineers, and computer scientists have always conducted such type of work. The knowledge generated by this research informs us how an artifact can be improved, is better than existing solutions, and can more efficiently solve the problem being addressed. It is important to note that artifacts are not exempt from theories. They rely on kernel theories that are applied, tested, modified, and extended (Walls et al. 1992). But there is considerable debate around the issue of whether there is a design theory or whether a science of design is even possible (NSF 2003; Hooker 2004).

1.6 The Spectrum of IS DSR

In all the definitions above, one can note that design is often a complex process and designing useful artifacts is hard due to the need for creative advances in domain areas in which existing theory is often insufficient. For our discipline, we are concerned with designing artifacts that use information technology (IT) and are applied to organizations and society in general. As Lee (2001) points out the characteristic that distinguishes IS from the other fields is as follows:

> Research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomenon that emerges when the two interact.

The term *artifact* is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally (Simon 1996). Such artifacts must improve upon existing solutions to a problem or perhaps provide a first solution to an important problem. IT artifacts, which are the end-goal of any design science research project, are broadly defined as follows:

- Constructs (vocabulary and symbols)
- Models (abstractions and representations)
- Methods (algorithms and practices)
- Instantiations (implemented and prototype systems)
- Better design theories

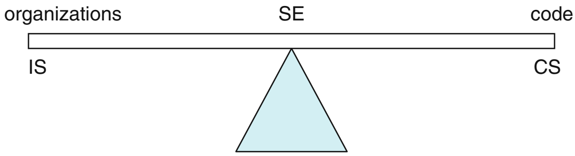
In both Herbert Simon's seminal work *The Sciences of the Artificial (1996)* and Nigel Cross' *Developing a Discipline of Design/Science/Research (2001),* we clearly see the importance they place on doing (construction). Simon believed that design is concerned with how things ought to be in order to attain goals (Gregor and Jones 2007). He saw the design process as generally concerned with finding a satisfactory design, rather than an optimum design. He believed "both the shape of the design and the shape and organization of the design process are essential components of a theory of design" (pp. 130–131). Cross on the other hand gives less importance to theory but stresses on knowledge that is acquired through the building process:

> We must not forget that design knowledge resides in products themselves; in the forms and materials and finishes which embody design attributes. Much everyday design work entails the use of precedents or previous exemplars – not because of laziness by the designer but because the exemplars actually contain knowledge of what the product should be (Cross 2001).

A research paradigm is the set of activities a research community considers appropriate to the production of understanding (knowledge) in its research methods or techniques. Historically, some communities have a nearly universal agreement on the phenomenon of interest and the research methods for investigating it. They are termed paradigmatic communities. There are other communities, however, where a number of different methods are appropriate. These are termed multi-paradigmatic communities. Information systems is an excellent example of a multi-paradigmatic community (Vaishnavi and Kuechler 2007).

Figure 1.2 shows the balance in scope of focus for three related disciplines: information systems (IS), software engineering (SE), and computer science (CS). CS researchers are much closer to actual working code. SE researchers are dealing with software at production and operational levels and they do have to face some organizational issues. IS researchers are closer to deployment of information technology in an organization. Hence besides working code, they face management and organizational challenges as well. The scope of focus also dictates the genesis of problems. This organizational focus bears on the specifications and eventual evaluation conducted. This would be discussed in more detail in Chapter 3.

Fig. 1.2 Discipline balance and scope of work scale



1.7 Difference Between Routine Design Practice and DSR

One source of confusion to novice design science researchers is to understand the subtle difference between conducting DSR versus practicing routine design. Is the iPod a good design or is it an example of design science research? If you break open the iPod and lay out its fundamental components, you will typically find memory, hard disk, CPU, some code, some audio input/output interfaces, and a song selection dial. None of these are new. They have existed for quite some time. But what the iPod did is to integrate them in a rather innovative way and produce an artifact that has tremendous value to music listeners. Is any new knowledge created in the process? Perhaps yes or perhaps no. It depends on whether the designers at Apple had actually invented something new with the compact design, the easy-to-use dial interface, or produced better sound clarity. They may have. In that case, if the team documents that their new "artifact" is better, faster, or more optimal through rigorous evaluation methods and comparison with similar artifacts, then new knowledge is indeed created and this would be considered DSR. But if no new knowledge is created, then this would be considered applying best practices and conducting routine design.

1.8 Conclusions

The information systems field has been energized by a flurry of recent activity that centers on the use of design research as an important research paradigm. We acknowledge that design research has broader appeal and knowledge has been created by several design fields. However, our community and the context of this book are information systems. Our goal is partly to legitimize design science as a valid method of doing research in the field. The other goal is to learn from related design disciplines and adopt successful design principles that can be appropriated for information systems research. In this book, we will explore the origins of DSR, its history, foundation, techniques, exemplars, and its future. Various techniques and methods will be discussed. Understanding the principles, theories, and foundations is the first step to ensure that you know when you are doing great design science research work.

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