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Design Science Research Methods and Patterns

Innovating Information and Communication Technology

Vijay K. Vaishnavi
William Kuechler Jr.

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Dedication

To my family for their love and support

Vijay K. Vaishnavi

Preface

The need for this work became clear during the first author's teaching of a research seminar course on design science research offered to doctoral students at Georgia State University over the past decade. The course focuses on research whose purpose is the improvement or innovation of ICT (information and communication technology) artifacts. This type of "improvement research" is identical in technique and philosophy to that conducted by numerous other research communities, including engineering and computer science, and yet we still have to find good published material that can be used for teaching students this type of research. Herbert Simon's book, *Sciences of the Artificial*, is a seminal work that has helped in realizing the uniqueness and importance of this type of research. The book, however, does not provide much guidance on how to perform this type of research.

A unique feature of this book is the use of *patterns* to present how to conduct design science research. The decision to use patterns to organize the knowledge presented here is based on our interest in patterns, the belief that patterns are an excellent mechanism for organizing and transmitting this type of knowledge, and the second author's positive experience with patterns during more than 20 years of ICT system design experience in industry. We firmly believe that over time we can find a set of patterns that can both communicate the goals and philosophy of design science research as well as provide firm direction to a researcher new to the discipline. In time, experienced design science researchers will hopefully also find this a useful explication and codification of some of the techniques they have used. We trust that the patterns presented here are a good start in this direction.

The ideas presented in this work have been shaped and influenced by the students in the research seminar course that the first author has taught. We would like to particularly mention the students in the 1996 offering of the course: Paul Cule, Gayle Dixon-Randall, David Gefen, Rich Klein, Bill Kuechler, Lynette Kvasney, George Littlejohn, and Linda Wallace; and the 1998 offering of the course: Ashley Bush, Gordon Depledge, Huoy Khoo, David Kuechler, Alisha Malloy, Amrit Tiwana, Rustam Vahidov, and Jie Yin. We would like to acknowledge their contributions to the patterns in this work and would like to thank them for their patience in learning the research process and tools through a systematic search

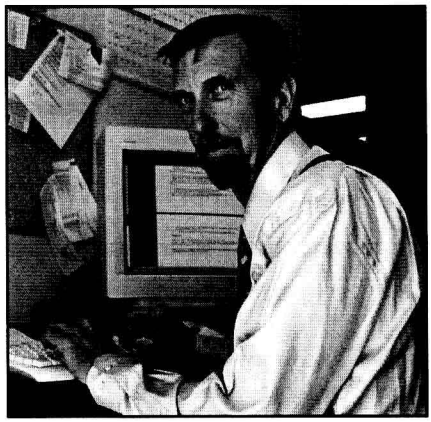
for the desired knowledge. We would like to particularly acknowledge the contributions of the 1998 class to the patterns presented in this work. We are sure this work will be further improved by the contributions made by the current and future classes taking this course. While acknowledging the contributions to this work from the design science research seminar students, we take responsibility for all errors or omissions.

The book can be used as a text or a reference for any course in the ICT fields that deals with the conduct of research, in particular design science research. Thus, the book can be used at the doctoral level, masters level, and senior undergraduate level in the ICT fields that include information systems, information sciences, information technology, and computer science. The book will also be useful for students conducting research in engineering fields.

Vijay K. Vaishnavi
William Kuechler Jr.

About the Authors

Vijay K. Vaishnavi is Board of Advisors Professor of Computer Information Systems at Robinson College of Business, Georgia State University. He holds a Ph.D. from the Indian Institute of Technology, Kanpur, and has conducted postdoctoral work at McMaster University, Canada. His research covers several areas, including process knowledge management, semantic interoperability and information integration, virtual communities and directory services, inter-organizational coordination, object modeling and design, and data structures. He has authored numerous research papers in these and related areas. The National Science Foundation and private organizations including IBM, Nortel, and AT&T have supported his research. His papers have appeared in *IEEE Transactions on Software Engineering, IEEE Transactions on Knowledge and Data Engineering, IEEE Transactions on Computers, SIAM Journal on Computing, Journal of Algorithms, Decision Support Systems*, and several other major international journals and conference proceedings. Dr. Vaishnavi is an IEEE Fellow, and a member of the IEEE Computer Society, the ACM, and the AIS.



William Kuechler Jr. is an associate professor of Information Systems at the University of Nevada, Reno. He holds a B.S. in Electrical Engineering from Drexel University, and a Ph.D. in Computer Information Systems from Georgia State University. His two primary research themes are the cognitive bases of IS use, development, and education, and interorganizational workflow and coordination. He has published in *MIS Quarterly, Communications of the ACM, IEEE Transactions on Knowledge and Data Engineering, Decision Support Systems, Journal of Electronic Commerce Research, IEEE Transactions on Professional Communications, Information Systems Management, Information Technology and Management, Journal of Information Systems Education,* the proceedings of WITS, HICSS, and other international conferences and journals. Dr. Kuechler is a member of the AIS and ACM.

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Chapter 1

Introduction

Until recently many researchers considered it impossible to *teach* research, at least in the same way that less complex skills such as reading or basic mathematics can be taught. This is because the practice of research is a complex activity requiring the extended use of several poorly understood cognitive activities such as creativity and intuition; research is, at best, a semi-structured activity. There are no algorithmic "recipes" for performing research, and even the methodologies for research sometimes presented (including those in this book) are guidelines at best.

In the past, those wishing to become researchers were expected to serve an apprenticeship, frequently by way of graduate study at a university, usually under the close tutelage of a senior researcher in the field. During the course of the apprenticeship, which extended over a period of years, the student researcher would gradually become "socialized" to the paradigmatic community in which they worked. If successful, the student was inculcated with an intimate and frequently tacit (that is, internalized and largely unstated) understanding of the research field, including:

- The important research questions
- The research methods that the community considers legitimate for exploring the research questions
- The prior research that provided the grounding of the field
- Knowledgeable colleagues
- Acceptable outlets for the research, including journals and conferences

This method of training researchers is still the dominant practice in many fields of research that are considered "paradigmatic" — areas that typically have a significant history (such as the hard sciences) and a dominant set of research questions,

methods for exploring them, and outlets for disseminating new knowledge. In contrast, information systems, along with many other disciplines centered on information and communication technology (ICT), are currently multi-paradigmatic; they draw research questions, methodologies, and grounding philosophies from multiple fields that are loosely united under a common interest in *understanding the way in which human-computer systems are developed, produce and process information, and influence the organizations in which they are embedded.* This book refers to these fields henceforward as ICT (information and communication technology) fields or disciplines.

It is because ICT is multi-paradigmatic that we felt the need to write this book. We believe researchers in ICT fields need a thorough grounding in each of the variety of research philosophies and techniques practiced in their field, and it simply is not practical for any student to undertake a multi-year apprenticeship in each of the major ICT research paradigms. Moreover, design science research as practiced in ICT fields is significantly different from the design-based research practiced in other fields (such as architecture or industrial design); the need for and manner of validation of research results, for example, is more emphasized in information systems (IS), human-computer interface (HCI), and many branches of software engineering due to the grounding of those fields in management science, psychology, and other statistically based descriptive disciplines.

The reason that design science research is applicable to ICT is due to some of the types of research questions that occur naturally in the field. Human-computer information producing and processing systems are, by their nature, complex and grounded in multiple disciplines. Questions frequently arise that have a sparse or nonexistent theoretical background, and exploring these is where design science research — exploring by building — excels. Cultures at all technological levels have always had the ability to build artifacts that produce useful results without fully understanding how the artifacts work or without being able to elucidate the principles that contribute to the making of good (or better) examples of the artifacts. Bridges, boats, and waterwheels are just three examples of important artifacts that were produced, used, and highly valued thousands of years before the physical principles underlying them were understood in a manner that enabled methodical, consistent performance improvement. In our culture, information systems are frequently constructed and used in a similar information vacuum: they do some useful work but no one is really sure how to make them better; they have significant effects on people and organizations, many unanticipated, and most poorly understood. Some schools of thought "instinctively" veer away from questions that lack a developed theoretical base to direct their experimentation. Design science research, on the other hand, thrives in just the sort of theoretical *terra incognita* that many areas of ICT still remain.

Another reason that emboldened us to write this book is that we felt the technique of the use of patterns — a formalized way of recording experience — would enable the written — as opposed to the verbal and imitative — communication of

at least some of the concepts, techniques, and their subtle interrelationships that make up research praxis. Tutorials on research in any field are rare, and the use of *patterns* in such a tutorial is unique as far as we know. However, the use of patterns to communicate contextually rich information will be familiar to many ICT fields, including software and computer engineering.

This book is structured as follows. Chapter 2 provides an introduction to design science research (DSR) in ICT that describes DSR in relation to other information systems (IS) research paradigms with a longer history, such as positivist and interpretivist research. IS is the specific ICT field of the authors but the discussion is immediately applicable to ICT fields in general. Chapter 2 also relates DSR in ICT to DSR as practiced in other areas of intellectual exploration where it has a much longer history. A primary contribution of the chapter is the introduction of the *design research cycle*, which is developed as the universal method for the practice of DSR. At the beginning of the "Patterns" section (Part II) of the book, this method is presented as a "roadmap" for the use of the patterns presented in the actual practice of DSR.

Chapter 3 places DSR in the historical context of ICT systems research and ICT artifact development and refinement. The design research cycle is abstracted to become a framework for understanding the progress of entire fields of technological research and development over extended periods of time. The intent of Chapters 1 and 2 is to give readers an overview of and "feel for" DSR even if the paradigm is unfamiliar to them. Those coming to ICT research from management science or other business backgrounds will find much of the material on DSR new and we urge them to read the introductory chapters carefully before proceeding to Part II. Those from a technical background such as engineering or physical science* will see many similarities to these areas of investigation, but will also, on careful reading, note significant differences between DSR as practiced in ICT and in other fields.

Part II of the book contains the patterns themselves. At the beginning of this section is a short chapter (Chapter 5) on "Using Patterns to Illuminate Research Practice." It begins by introducing patterns as they are used in this book. The qualifier "as used in this book" is necessary because, although patterns are used in many fields for many purposes, a precise general definition has proven elusive. The chapter then draws on concepts from the introductory chapters and outlines a methodology for the practice of DSR that is keyed to the patterns presented in the remainder of the book. The patterns are grouped by chapter, with each chapter being applicable to one or more phases of the research methodology.

The book concludes with Part III, in which examples of published design science research, including some widely cited papers, are elaborated in terms of the patterns used (or could have been used) in the research program.

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* Other fields, such as Education, also utilize DSR (DSSE, 1997), however, in practice, few students with a background in education proceed on to graduate work in ICT fields.