Reference Syllabi

Association for Information Systems (AIS)

Design Science Research in Information Systems

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Background

The Design Science Research (DSR) paradigm has its roots in the sciences and engineering of the artificial. It is fundamentally a problem-solving paradigm. DSR seeks to enhance human knowledge with the creation of innovative artifacts. These artifacts embody the ideas, practices, technical capabilities, and products through which information and computing technology and systems (abbreviated here as the field of Information Systems (IS)) can be efficiently developed and effectively used. Artifacts are not exempt from natural laws or behavioral theories. To the contrary, their creation relies on existing laws and theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem solving capabilities of the researcher. Thus, the results of DSR include both the newly designed artifact and a fuller understanding of the theories of why the artifact is an improvement to the relevant application context.

Design activities are central to most applied disciplines. Research in design has a long history in many fields including architecture, engineering, education, psychology, anthropology, and the fine arts. The IS field since its advent in the late 1940's has appropriated many of the ideas, concepts, and methods of DSR that have originated in these other disciplines. However, IS as composed of inherently mutable and adaptable hardware, software, and human interfaces provide many unique and challenging design problems that call for new and creative research methods.

The community of DSR scholars in the IS field has grown significantly over the past 30 years. Publication opportunities have expanded in the top IS journals and the top IS conferences feature tracks devoted to DSR scholarship. In particular, the annual Design Science Research in Information Systems and Technology (DESRIST) conference is devoted to presentation of the best DSR papers from the international IS community.

Purposes and Objectives

The design science research (DSR) paradigm is highly relevant to IS research because it directly addresses two of the key issues of the discipline: the central role of the IS artifact and the importance of professional relevance of IS research. DSR follows a pragmatic research paradigm that calls for the creation of innovative artifacts to solve real-world problems and to address promising opportunities. DSR in IS involves the construction of a wide range of *socio-technical* artifacts such as decision support systems, modelling tools, governance strategies, methods for software systems development and evaluation, and system change interventions. Thus, DSR in IS combines a focus on the designed artifact with a high priority on relevance in the application domain.

This course provides a comprehensive introduction to the basic concepts and principles of design science research applied to the IS field. The course develops skills for implementing and evaluating the techniques and methods that are used in the various phases of DSR. Research methods and techniques used in the various phases of such research will be discussed in the context of exemplars. Common methods that are used in both the important phases of design research, namely, building and evaluation, will be covered. Managing design projects for commercial clients and their issues are also discussed. The exemplars will be from a number of information systems areas such as software engineering, networking, Internet technologies, information security, medical IS and telemedicine, database, e-commerce, wireless information systems and others.

The key to appreciating the core ideas and goals of DSR is a clear understanding of how DSR relates to human knowledge. The appropriate and effective consumption and production of knowledge are related issues that researchers should consider throughout the research process – from initial problem selection, to the use of sound research methods, to reflection, and to communication of research results in journal, magazine, and conference articles. Each of the course units includes a list of learning objectives that give the student the understanding and the skills to perform rigorous and relevant DSR in selected application areas.

Structure

INTRODUCTION – WHAT IS DESIGN?

Overview

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." Designs are the instructions based on knowledge that turn things into value that people use. It embodies the instructions for making the things. A number of disciplines have all made design a central element in what they do. This includes architecture, engineering, computer science, software engineering, 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 familiar with beautiful architectures that capture our imagination. Mitch Kapor states 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.

The goal in this course unit is to understand design and its role in both the academic discipline and practice we call Information Systems (IS). Design in Information Systems is both an iterative process (set of activities) and a resulting product (artifact) – a verb and a noun. Very simply stated, design in information systems deals with building socio-technical artifacts which solve a human problem. The designed artifact must be evaluated to show that not only does it solve the problem but does it in an efficient manner by providing clear and compelling utility to its user.

Learning Outcomes

After the unit participants will be able to

- Understand the meaning and important of design
- Describe the pervasive nature of design across many disciplines
- Demonstrate the innovative and transformative power of design

- Describe the role of design in Information Systems

Material

- Cross, N. (2001). "Designerly Ways of Knowing: Design Discipline vs. Design Science," *Design Issues* (17:3), pp. 49-55.
- Cross, N. (2011). *Design Thinking*, Oxford, UK: Berg Publishing.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapter 1.
- March, S., and Smith, G. (1995). "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15), pp. 251-266.
- Walls, J., Widemeyer, G., and El Sawy, O. 1992. "Building an Information System Design Theory for Vigilant EIS," *Information Systems Research* (3:1), pp. 36-59.
- Winograd, T. (1996). *Bringing Design to Software*, Addison-Wesley.

DESIGN SCIENCE RESEARCH FUNDAMENTALS

Overview

Design Science Research is inherently a problem-solving process. The fundamental principle is that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact. DSR implements IS artifacts within an application context (e.g., a business organization) for the purpose of improving the effectiveness and efficiency of that context. The utility of the artifact and the characteristics of the application -- its work systems, its people, and its development and implementation methodologies -- together determine the extent to which that purpose is achieved. Researchers in IS produce new ideas to improve the ability of humans, groups, and organizations to adapt and succeed in the presence of changing environments. Such new ideas are then communicated as knowledge to the relevant IS stakeholders and communities. March and Smith (1995) identify two design processes and four design artifacts produced by DSR in IS. The two processes are *build* and *evaluate*. The artifacts are *constructs*, *models*, *methods*, and *instantiations*.

In this unit, the basic concepts and principles of DSR are surveyed with a focus on its application in IS contexts. The seminal papers in the field are surveyed to provide students with a fundamental understanding of how to perform rigorous and relevant DSR projects.

Learning outcomes

After the unit participants will be able to

- Understand the synergy between natural science research and design science research
- Describe the types of design artifacts in DSR
- Describe the types of design processes in DSR
- Apply the guidelines for DSR to projects
- Identify important problems and opportunities for DSR projects
- Understand the role of knowledge consumption and production in DSR
- Explain the levels of artifact abstractions that can be DSR knowledge contributions
- Describe the four quadrants of the knowledge contribution matrix and the types of projects that fit into each quadrant
- Know how to organize an effective DSR presentation

Material

- Gregor, S. and Hevner, A. (2013). "Positioning and Presenting Design Science Research for Maximum Impact," *Management Information Systems Quarterly*, Vol. 37, No. 2, pp. 337-355.
- Gregor, S., and Jones, D. (2007). "The Anatomy of a Design Theory," *Journal of the Association of Information Systems,* (8:5), pp. 312-335.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapters 2-5.
- Hevner, A., March, S., Park, J., and Ram, S. (2004). "Design Science Research in Information Systems," *Management Information Systems Quarterly*, Vol. 28, No. 1, pp. 75-105.

- March, S. and Smith, G. (1995). "Design and Natural Science Research on Information Technology", *Decision Support Systems*, 15, pp. 251-266.
- Nunamaker, J., Chen, M., and Purdin, T. (1990-91). "Systems Development in Information Systems Research," *Journal of Management Information Systems* (7:3), pp. 89-106.
- Simon, H. (1996). *The Sciences of the Artificial* (3rd ed), Cambridge, MA: MIT Press.
- Vaishnavi, V. and Kuechler, W. (2015). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*, CRC Press.
- Walls, J., Widmeyer, S., and El Sawy, O. (1992). "Building an Information System Design Theory for Vigilant EIS", *Information Systems Research*, 3:1, pp. 36-59.

PERFORMING DESIGN SCIENCE RESEARCH

Overview

The practical challenges of performing DSR projects has led to several proposed process models for scheduling and coordinating DSR activities. Seminal thinking in this area was achieved by Nunamaker and his research group at the University of Arizona (Nunamaker et al. 1990-91). They claim that the central nature of systems development leads to a multi-methodological approach to IS research that consists of four research strategies: theory building, experimentation, observation, and systems development. Vaishnavi and Kuechler (2015) extend the General Design Cycle model of Takeda et al. (1990) to apply specifically to DSR. Peffers et al. (2008) propose and develop a design science research methodology (DSRM) for the production and presentation of DSR. A unique feature of this model is the inclusion of four possible entry points: problem-centered initiation, objective-centered solution, design and development-centered initiation, and client/context initiation. This unit also covers the Action Design Research (ADR) process that integrates the ideas of action research with DSR (Sein et al. 2011).

Learning outcomes

After the unit participants will be able to
- Describe the activities required to perform a DSR project
- Describe the flows among activities in the DSR process model
- Understand the different DSR process models
- Develop a DSR process for their own DSR project
- Apply the ideas of action research to a DSR project

Material

- Baskerville, R., Kaul, M., and Storey, V. (forthcoming). „Genres of Inquiry in Design-Science Research: Justification and Evaluation of Knowledge Production," *Management Information Systems Quarterly*.
- Hevner, A. (2007). "A Three Cycle View of Design Science Research," *Scandinavian Journal of Information Systems* (19:2), pp. 87-92.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapter 13.
- Nunamaker, J., Chen, M., and Purdin, T. (1990-91). "Systems Development in Information Systems Research," *Journal of Management Information Systems* (7:3), pp. 89-106.
- Peffers, K., Tuunanen, T., Rothenberger, M. and Chatterjee, S. (2008). "A Design Science Research Methodology for Information Systems Research," *Journal of MIS* (24:3), pp. 45-77.
- Sein, M., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. (2011). "Action Design Research," *Management Information Systems Quarterly* (35:1), pp. 37-56.
- Takeda, H., Veerkamp, P., Tomiyama, T., and Yoshikawam, H. (1990). "Modeling Design Processes," *AI Magazine*, Winter, pp. 37-48.
- Vaishnavi, V. and Kuechler, W. (2015). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*, CRC Press.

DESIGN SCIENCE RESEARCH EVALUATION

Overview

Evaluation is an especially critical activity in DSR. The designed IT artifact is a socio-technical entity that exists within an environment (business or social) which lays out the requirements for its evaluation. Such evaluation of IT artifacts requires definition of appropriate metrics and possibly the gathering and analysis of appropriate data. IT artifacts can be evaluated in terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes.

In this unit, it is our goal to help the reader understand the different issues, questions, methods, and techniques that arise when one does evaluation. The goal is to provide the researcher with sufficient knowledge of the diverse evaluation techniques so that they will learn to ask the right questions, know when to apply which technique, and be confident in the quality of the results as evidence for the goodness of the design artifact. Extending the ideas of evaluation beyond usefulness to sustainable and evolvable designs is an important goal for the future of DSR.

Learning outcomes

After the unit participants will be able to

- Explain the importance of rigorous DSR evaluation
- Determine the evaluation requirements for a design project and a specific application environment
- Know the criteria necessary for the evaluation of DSR artifacts
- Understand the various DSR evaluation techniques
- Select the most effective evaluation techniques for a DSR project
- Know how to perform rigorous evaluations
- Present the evaluation results to the different stakeholders
- Extend the meanings of evaluation to include broader criteria of design fitness and design utility

Material

- Gill, T. and Hevner, A. (2013). "A Fitness-Utility Model for Design Science Research," *ACM Transactions on Management Information Systems*, Vol. 4, No. 2, Article 5, 24 pages.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapters 9-10.
- Hevner, A., March, S., Park, J. and Ram, S. (2004). "Design Science Research in Information Systems," *Management Information Systems Quarterly*, Vol. 28, No. 1, pp. 75-105.
- Venable, J., Pries-Heje, J., and Baskerville, R. (2014). „FEDS: A Framework for Evaluation in Design Science Research," *European Journal of Information Systems*, PP. 1-13.

DESIGN SCIENCE RESEARCH AND DESIGN THEORY

Overview

The type of theory that formalizes knowledge in DSR is termed design theory in Gregor's (2006) taxonomy. This type of theory gives prescriptions for design and action: it says how to do something. Walls et al. (1992), early proponents of design theory in IS, stress that a design theory must include components that are at a meta-level. A design theory "does not address a single problem but rather a class of problems." Extending this stream of thought, Gregor and Jones (2007) propose that a DSR project should produce a design theory or provide steps towards a design theory. Their view, as expressed similarly in other branches of science, is that all research should result in a contribution to knowledge in the form of partial theory, incomplete theory, or even some particularly interesting and perhaps surprising empirical generalization in the form of a new design artifact.

The goal of this unit is to support researchers to a clear understanding of the role of design theory and what theoretical contributions can be claimed in a DSR project. The decision whether to present DSR results as design theory will depend on the levels of artifact abstraction and desired generality in the research (Gregor and Hevner 2013). An artifact that is presented with a higher degree of abstraction can be generalized to other situations and is more mature than a simple descriptive case study of what happened in one situation. What distinguishes design theory, however, is that it includes kernel theory to explain why the artifact works.

Learning outcomes

After the unit participants will be able to

- Explain the role of theory in research
- Explain the meaning of design theory
- Describe clear representations of design theory
- Understand how DSR uses existing kernel theories and design theories
- Understand how DSR produces different abstract levels of design theory
- Understand when design theory is an appropriate and achievable research result
- Develop appropriate design theories for DSR projects

Material

- Chatterjee, S. (2015). "Writing my Next Design-Science Research Master-Piece: But How Do I make a Theoretical Contribution to DSR?", *Proceedings of the 22nd ECIS*, Munster, Germany.
- Dubin, R. (1978). *Theory Building* (Rev. edn.), New York, NY: The Free Press.
- Gregor, S. (2006). "The Nature of Theory in Information Systems," *MIS Quarterly,* (30:3), pp. 611-642.
- Gregor, S. and Hevner, A. (2013). "Positioning and Presenting Design Science Research for Maximum Impact," *Management Information Systems Quarterly*, Vol. 37, No. 2, pp. 337-355.
- Gregor, S., and Jones, D. (2007). "The Anatomy of a Design Theory," *Journal of the Association of Information Systems,* (8:5), pp. 312-335.
- Gregor, S., Muller, O., and Seidel, S. (2013). "Reflection, Abstraction, and Theorizing in Design and Development Research," *Proceedings of the 21st ECIS*, Utrecht, NL.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapter 4.
- Mandviwalla, M. (2015). „Generating and Justifying Design Theory," *Journal of the Association for Information Systems* (16, 5).
- Sutton, R. and Staw, B. (1995). "What Theory is Not," *Administrative Sciences Quarterly* (40:3), pp. 371-384.
- Walls, J., Widemeyer, G., and El Sawy, O. (1992). "Building an Information System Design Theory for Vigilant EIS," *Information Systems Research* (3:1), pp. 36-59.

DESIGN SCIENCE RESEARCH SPECIAL TOPICS

Overview

This unit gives the course designer and the instructors an opportunity to include special topics as they relate to and apply DSR. Recent and on-going DSR projects can be included in the course based on the expertise and research interests of the students and instructors. We propose that anywhere from 20% to 40% of the course content could be devoted to covering the application of DSR in special topic areas. Each topic area will be covered by the inclusion of exemplar DSR conference and journal papers from the area.

As examples of DSR special topics, course units on the following research topics can be included:

- Software system design
- Organizational design and managerial processes
- Energy informatics design
- Human-Computer interaction design
- Neuroscience and design
- Innovation and design

- Medical informatics and telemedicine design
- Networking and Internet technology design
- Cloud-based IS design
- Mobility and design

Learning Outcomes

After the unit participants will be able to
- Understand the use of DSR methods in special topic areas of IS and other fields
- Apply DSR concepts and methods to other design-oriented disciplines
- Plan DSR projects across inter-disciplinary boundaries

Material (Instructors will use exemplar DSR papers from the selected special topic areas)

- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Chapters 11-16.

DESIGN SCIENCE RESEARCH EXEMPLARS

Overview

Throughout this course it is important for students to be exposed to the best examples of DSR projects and published papers. A listing of exemplar DSR publications provides a starting point for exploring some of the most significant DSR contributions of the IS field. In addition, students may want to survey papers from recent DESRIST Proceedings to explore cutting edge DSR directions. The goals are to highlight recent thinking on design science theories and research practices and to study exemplar design science papers in order to contribute to a greater understanding of DSR in the IS community. Students are well trained in a discipline by seeing its best practices in action. Communicating IS design science theories and research practices is essential not only to support acceptance among IS professionals but also to establish the credibility of IS DSR among the larger body of design science researchers in computer science, engineering fields, architecture, the arts, and other design-oriented communities.

Learning Outcomes

As a suggested assignment, each student (or two-person team) will select an exemplar DSR paper from the Information Systems literature. (A list of exemplar papers can be found in the references below or students may select a DSR paper of personal interest with instructor approval.) Students will read the selected papers and will prepare an in-depth critique of how the researchers performed and presented the DSR project. Consider the following questions:
- Did the project presentation address appropriately DSR guidelines? How well?
- What is the research artifact?
- What forms of evaluation were performed in the study?
- Was a 'design theory' developed in the presentation?
- Where is the project located on the knowledge contribution framework?
- What are the new contributions of the research? To the knowledge base? To the application environment?
- What is your overall critique of the research project?
- What improvements would you suggest to the performance or presentation of the research project?
- What future research directions would you propose for the project?

Deliverables

- Each student or team will present a brief summary of their findings to the class. Presentations of 3-5 slides may be shown. The class will discuss the paper. In this way, students will be exposed to a wide range of exemplar DSR papers.

- Each student or team will submit a 5-page white paper with an in-depth critique of the exemplar paper to the instructor.

Material (Lists of exemplar DSR papers can be found in the following references)

- Arnott, D. And Pervan, G. (2012). „Design Science in Decision Support Systems Research: An Assessment Using the Hevner, March, Park, and Ram Guidelines," *Journal of the Association for Information Systems*, (13: 11), pp. 923-949.
- Gregor, S. and Hevner, A. (2013). "Positioning and Presenting Design Science Research for Maximum Impact," *Management Information Systems Quarterly*, Vol. 37, No. 2, pp. 337-355.
- DESRIST Proceedings (2006 to 2015)
- Hevner, A. (2008). Volume Editor, "Design Science Theories and Research Practices" Volume III in the *SAGE Major Currents in Information Systems Series*, Editors – L. Willcocks and A. Lee, SAGE Publications, Inc., Thousand Oaks, CA.
- Hevner, A., and Chatterjee, S. (2010). *Design Research in Information Systems*, New York: Springer Publishing, Appendix B.

APPLICATION OF DESIGN SCIENCE RESEARCH IN STUDENT PROJECTS

Overview

This course will give students the abilities to:

- Understand the DSR paradigm, to include ideas, concepts, theories, processes, and knowledge contributions
- Analyze the effective use of DSR in IS research projects and papers
- Identify interesting and relevant problems and opportunities that require DSR solutions
- Apply DSR in their own research projects
- Creatively Build innovative artifacts
- Rigorously Evaluate artifacts on how they satisfy requirements in the application context
- Transfer the innovative artifacts into use in real-world environments
- Contribute new knowledge to the research field of application

Learning Outcomes

To assess the above learning objectives, a student DSR project is suggested as a required assignment. Based on personal research interests, each student will develop a proposal for a DSR project. The proposal should have an introduction motivating the problem, a description of the problem to include the application environment, research questions, clear DSR processes to be followed in conducting the research, the proposed build and evaluate methods and their appropriateness, and the expected research contributions. A brief literature survey should be included as time permits. The positioning of the DSR project in regards to the knowledge contribution framework should be addressed.

Deliverables

- Each student will choose a particular topic (domain) of his/her interest. The problem should be clearly described. Keep in mind that the problem should have scale and scope so that the student will remain interested in it for the entire semester as well as later work on for a possible research paper and/or dissertation. The student will develop an actual design science research paper around this problem. Each student will develop a set of research questions to be investigated with DSR. The instructor will be available for discussion and help to formulate the research questions and design.
- The student is expected to read at least 12 to 15 (possibly more) journal and conference articles that are related to the topic so that s/he can begin to formulate his/her own unique solution.

- Each student will present a research proposal to the class. Presentations of 3-5 slides may be shown. The class will provide feedback. Depending on class size, the presentation and feedback session will be scheduled for 20 to 30 minutes.
- At the mid-point of the semester, each student will submit a written DSR research proposal to the instructor. Feedback comments will be provided.
- The final deliverable as a research paper should be suitable for submission to a conference such as DESRIST, WITS, HICSS, or any suitable IEEE/ACM/AIS venue. The student will also make an oral presentation of this research paper. The student needs to argue why the proposed research is important, and why there is reason to believe that the research will be successfully completed.

Material (Example student papers from previous course offerings can be made available for student review. In particular, published conference/journal papers resulting from student papers would be greatly motivating DSR exemplars.)

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