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Lascelles Adams
Univ. of Central Florida

Ouafaa Elgarah
Univ. of Central Florida

Sandra Richardson
Univ. of Memphis

James Courtney
Univ. of Central Florida

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Lascelles Adams
Univ. of Central Florida, Orlando, FL., USA
ladams@bus.ucf.edu

Ouafaa Elgarah
Univ. of Central Florida, Orlando, FL., USA
welgarah@bus.ucf.edu

Sandra Richardson
Univ. of Memphis, Memphis, TN, USA
srichardson@bus.ucf.edu

James Courtney
Univ. of Central Florida, Orlando, FL., USA
jcourtney@bus.ucf.edu

ABSTRACT

Environmental decision support systems (EDSS) involve both theoretical and applied concerns. Theoretical in terms of decision making and applied in terms of the development of actual systems to support decision making related to environmental issues. In this paper we describe a general research framework for conducting IS design research (the DAGS model), and show how that model is relevant to EDSS research. We argue that the dual goals of contributing to both theory and practice can at least in part be realized by more emphasis on the use of engineering and architecture as reference disciplines, and the use of Design science, Action research, Grounded theory, and Systems development as the components for this framework. The framework is illustrated with projects related to environmental issues.

Keywords

Action research, design science, grounded theory, systems development, environmental decision support systems.

INTRODUCTION

IS research should be regarded as more of an *applied* discipline rather than a *basic/pure* research discipline (Moody and Buist, 1999). Applied disciplines have two primary objectives: (1) to increase (theoretical) knowledge: to understand why things happen in a particular context, and (2) to improve practice by conducting research that will ultimately yield useful social and organizational benefits. We believe that such a perspective is especially important in information systems and decision support systems that relate to environmental issues. The study of global warming, for example, requires not only the development of theoretical models to understand and predict the results of this phenomenon, but also the application of those models to real data and ultimately the incorporation of knowledge from such studies into governmental and business policies.

The objective of this paper is to describe the multi-methodological DAGS framework – Design science, Action research, Grounded theory and System development (Adams and Courtney, 2004), and discuss its relevance to environmental decision support systems. The intent of this model is to encourage the IS research community to synthesize and utilize new research methods and paradigms that will help improve not only IS theories, but also the contribution of IS research to business practice. We argue that the dual goals of contributing to both theory and practice can at least in part be realized by more emphasis on the use of engineering and architecture as reference disciplines, and the use of design science, systems development, grounded theory, and action research as the components for this framework. This model is especially relevant to EDSS because it correlates well with the need to integrate theory and practice in order to deal with environmental issues.

THE DAGS FRAMEWORK

The DAGS framework, which integrates design science, systems development, action research and grounded theory methodologies in leveraging technology to achieve business effectiveness through relevancy of IS research, is illustrated in figure 1. The framework retains systems development as its core activity.
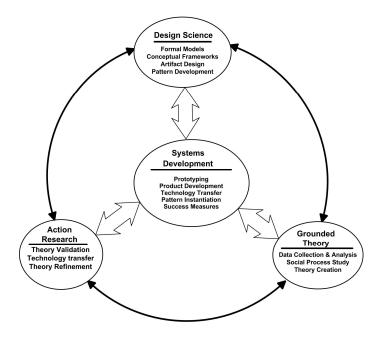
Figure 1: The DAGS Framework

The elements of the DAGS framework consist of *theory building* approaches such as design science and grounded theory and *theory testing and refinement* approaches such as system development and action research. A specific research project might combine these elements in various ways to develop a strategy for achieving both theoretical and practical objectives, and is thus epistemologically neutral. That is, we propose adopting whatever views of knowledge and whatever methodologies seem most appropriate for a given context. For example, a project might begin with Churchman's (1971) theory of inquiring systems as the basis for knowledge management systems in organizations, and use design science and systems development as ways of instantiating the theory, with tests of the resulting prototype as constituting proof of concept (Figure 2a).
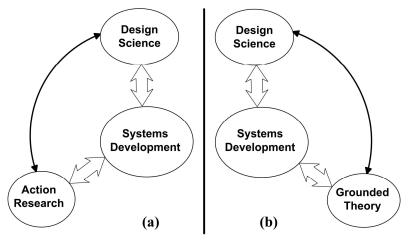
Figure 2: DAGS Theory Building Approaches

On the other hand, in the absence of theory in the domain of interest, one might begin with a grounded theory approach, develop a theory of phenomena in the domain, and then use design science and systems development as ways of testing and refining the theory (Figure 2b). Next we describe the elements of the framework and then show how they may be fitted together to form programs of research.

Design Science ("D")

Design is central to the information systems and DSS disciplines (Markus et al., 2002; Lindgren et al., 2004); its benefits include providing researchers a basis for making predictions about system use, patterns and impacts; and making problems

more manageable for developers (Markus et al., 2002). MIS has a long history of examining the role of design theory. The literature has evolved and has refined the general systems approach, addressing specific issues and concerns in IS design. Design science seeks to create innovations that define the ideas, practices, technical capabilities, and products through which analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished (Hevner 2004).

Several researchers (Au, 2001; Ball, 2001; Moody and Buist, 1999) have argued that architecture, in the form of design science, can become a reference discipline for IS research, because it will facilitate the development and evaluation of systems that are sound and suitable for commercial deployment. March and Smith (1995) believe that design science is technology oriented and attempts to create things that serve human purposes, as opposed to natural and social sciences, which try to understand "reality." March and Smith characterized design science products or outputs as being of four types: constructs, models, methods and implementations. In a design science context, the development of constructs, models, and algorithms constitutes theory building, and implementations constitute theory testing.

Walls, et al. (1992) argued that design theories have several characteristics. They are prescriptive and must deal with goals as contingencies. They can never involve pure explanation or prediction. They are composite theories which encompass kernel theories from natural science, social science and mathematics. Additionally, while explanatory theories tell "what is", predictive theories tell "what will be", and normative theories tell "what should be", design theories tell "how to/because." Furthermore, they show how explanatory, predictive, or normative theories can be put to practical use. Design theories are theories of procedural rationality (Walls et al., 1992, p. 41).

As an applied discipline, the research conducted in information systems arena should be relevant to the needs and practices of the business community. There should be a bidirectional flow of information between research and practice, researcher and practitioners. Design science is especially valuable today because it facilitates and utilizes this bi-directional information flow in applying technology to satisfy the organizational needs and demands of the marketplace, forcing the enterprise, especially IS professionals, to utilize new methods and modes of operation in order to remain competitive.

Action Research ("A")

Action research is defined "as doing research with and for people, rather than doing research on them" (Cave and Ramsden, 2000); it aims to solve current practical problems while expanding scientific knowledge (Lindgren et al, 2004) and is particularly appropriate for the development of systems design principles (Walls et al, 1992). It is a clinical method that puts IS researchers in a helping role with practitioners (Baskerville and Myers 2004).

Action research incorporates three elements, participation, equality between researchers and participants, and praxis, which include reflexive action (Cave and Ramsden, 2002). It empowers people by involving them in research (White, 2005), and its strength lies in the combined ability of practitioners and researchers to influence practice while systematically collecting data (Cave and Ramsden, 2002).

Action research attempts to link theory and practice, thinking and doing, achieving both practical and research objectives (Susman and Evered (1978). By emphasizing collaboration between researchers and practitioners, action research would seem to represent an ideal research method for information systems especially because of its ability to address complex real-life problems. However, Kock et al (1997) described three threats to action research projects: *uncontrollability, contingency* and *subjectivity* threats. He also offers "antidotes" to deal with these threats, one of which is a grounded theory approach. Space limitations preclude a discussion of these threats and antidotes, however, we do incorporate grounded theory as an element of our framework, and it is described next.

Grounded Theory ("G")

Grounded theory is "an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data." (Martin and Turner, 1986, p. 143) The term "Grounded Theory" implies that theory is developed from a systematic analysis of empirical data; therefore, a grounded theory is one that is derived from the study of a phenomenon and is verified through data collection and analysis. It begins with data, not theory, and is thus a theory building technique.

The main objective of grounded theory is the discovery of a theoretically comprehensive explanation about phenomena, using techniques and analytical procedures that enable investigators to develop a theory that is significant, generalizable, reproducible and rigorous. Using the prescribed methodology, one does not begin with a theory and then prove it. Rather, a theory emerges from the observations and generated data. The emergent theory can be empirically tested to develop forecasts or predictions from general principles (Strauss and Corbin, 1990). Therefore, we can describe the association between data collection, analysis and theory as reciprocal.

The grounded theory methodology is comprised of flexible strategies that guide qualitative data collection and the methodology's strength lies in its ability to convey: (a) the steps for handling data collection and analysis; (b) a way of correcting errors, omissions and of refining analytic ideas; (c) tools for studying basic social and social psychological processes in their natural settings; and (d) strategies for creating middle-range theories (Charmaz, 2002). Grounded theory methodology prescribes specific events for data collection and analysis (Strauss and Corbin, 1990), with limited flexibility and latitude so rigor can be maintained throughout the project.

Grounded theory methods are emergent both in type and nature of data and analysis throughout the research process. The purpose of grounded theory strategies is to support the development of middle-range theories. By definition, middlerange theories are theories that are moderately abstract, inclusive, organized within a limited scope, have a limited number of variables, testable in a direct manner and have a strong relationship with research and practice. Each stage of the grounded theory analysis moves the work toward theoretical formulations and the techniques involved in the strategies employed: coding, memo-making, and theoretical sampling, all serve to build theory (Charmaz, 1994).

Systems Development ("S")

The use of system development (SD) as a research methodology has been argued and defended by many IS researchers (Nunamaker and Chen, 1990, Nunamaker et al., 1991, Gregg et al., 2000, Burstein and Gregor, 1999). Orlikowski and Iacono (2001) strongly propose that IT artifact, by itself, should be a central phenomenon to focus on IS research. System development presents a viable research methodology that researchers can use to fill the gap between the social and technological aspect of IS research. SD has been classified as constructive research method (Iivari et al. 1998). Constructive methods, according to Iivari et al (1998, p.175) are concerned with "the engineering of artifacts, which may be either purely conceptual or more technical." Concomitantly, Nunamaker et al. (1990) argue that system development is a central part of a multi-methodological approach to IS research. This pivotal role of system development stems from the fact that the developed system serves both as a proof-of-concept for the fundamental research and provides an artifact that can become the focus of other research project.

Systems development is not simply developing a piece of software. In fact, Nunamaker et al. (1990, p. 103) posit that "building a system in and of itself does not constitute research." However, the synthesis and expression of new technologies and new concepts in a tangible product can act as both the fulfillment of the contributing basic research and as an impetus to continuing research (Nunamaker et al. 1990, p.103).

The rigor of the SD as a research methodology has been questioned and the evaluation criteria issues have been raised by many researchers (Weber, 1987). Nunamaker et al. (1990) proposed five criteria to which SD research must conform (p. 101): (1) the purpose is to study an important phenomenon in areas of information systems through system building, (2) the results make a significant contribution to the domain, (3) the system is testable against all the stated objectives and requirements, (4) the new system can provide better solutions to IS problems than existing systems, and (5) experience and design expertise gained from building the system can be generalized for future use.

System development methodology has been suggested as an ideal domain for the use of action research (Baskerville and Wood-Harper, 1996). In fact, in a study conducted by Lau (1997) where he reviewed articles that have used action research over a twenty-five year period found that 11 out of the 30 articles were categorized as system development. Additionally, Parker et al. (1994) argue that system development is a form of action research when the researcher is involved in the construction and testing of a method or an information system in real-world setting.

THE DAGS FRAMEWORK IN ACTION

In this section, we describe two of these research projects, one of which relates to an EDSS for helping manage a threatened species, the Florida scrub-jay, and another that involves the development of a DSS design methodology for contentious environments such as those found in EDSS situations.

Development of an EDSS for Florida Scrub Habitat

The US Endangered Species Act of 1973 was in part a response to the environmental ethics movement which, among other questions, asks whether it is moral for us to knowingly allow the extinction of a species through the actions of humans. The Act protects not only the species on the endangered or threatened list, but also the ecosystems on which they depend. The Florida scrub-jay, found only in the state of Florida, is protected as threatened on the endangered species list. Its survival depends critically on scrub habitat, as that is the only environment in which it can survive.

Banyan and Malatesta (2000) described the Florida scrub-jay and its predicament in the Premier issue of EcoFlorida. They indicate that scrub-jays mate for life and are highly territorial. A breeding pair relies on the establishment of a permanent

territory of about 25 acres in scrub habitat. Broods stay within the same territory, essentially establishing an extended family that protects its territory from other Florida scrub jay families. Hence it is difficult if not impossible for displaced families to move to a new habitat. The most recent population count is just a little over 2000 birds located mostly in the region near Kennedy Space Center with others in the Ocala National Forest and the Kissimmee State Park. The birds are continuing to decline in numbers.

The scrub itself is a very dry habitat with trees less than 10 feet tall, wide apart and providing little canopy cover. Many of the plants are less than a foot tall and the space is quite open. Nests are typically about 8 feet off the ground. This dry, open habitat is easily developed and rapidly giving way to urbanization and agriculture.

To develop on lands that are occupied by scrub-jays, the property owner and/or developer must enter into a process called a Habitat Conservation Plan which includes a mitigation element. Mitigation may be done by setting aside two acres of scrub for each acre developed, or by paying a fee of $22,726 per acre, but the 2:1 ratio holds here also, so the fee is effectively $45,552 per developed acre. Fees are collected by the United States Fish and Wildlife Service used for the purchase of scrub habitat to benefit the long term survival of scrub-jays.

An obvious question here is whether mitigation fees will be sufficient to maintain scrub-jay habitat in the future. An environmental DSS to forecast land costs for scrub habitat and mitigation fee revenue to see if fee income can be expected to keep pace with costs (Courtney, et al., this volume). This project illustrates the DAGS framework in that it involves the design and development of a DSS planning model for fee revenue and land costs. It is an action research project being conducted in conjunction with a county in Florida with data from a GIS database and county tax rolls. It does not involve the use of grounded theory, but does involve the other three elements of the framework. It instantiates environmental ethics theory in the sense that it attempts to maintain the existence of a species that might possibly be made extinct simply by human action. This is a sensitive and contentious issue that brings developers and environmentalists head-to-head. Unfortunately, it is unclear at this point whether this project will be allowed to continue. The next section describes another environmentally related DSS project which also contains contentious issues.

Decision Support Systems for Contentious Situations: Application to Zoning Decisions

The multi-methodical approach presented by the DAGS framework has been applied to the development, validation and testing of a design theory for Decision Support Systems in contentious situations. Contentious situations are characterized by the multiplicity of stakeholders involved and the pervasive nature of conflicts among their perspectives. The proposed design theory, multiple perspective dialectic process (MPDP) is based on the multiple perspective approach advocated by Mitroff and Linstone (1993) and the dialectic process. This new approach is well suited for complex decisions. It calls for the integration of different perspectives including the technical, organizational, personal and ethical concerns. The design process consists of identifying relevant stakeholders, their respective worldviews, and conflicts in these worldviews. A design (thesis) and "counter design" (antithesis) are created, and prototype systems based on these designs are developed. The prototypes are presented to stakeholders who engage in a dialogue and a synthesis is formed. The process is repeated until all conflicts are resolved or resources are exhausted, and a final system is produced. Details of the MPDP design methodology can be found in Elgarah et al. (2002).

In this research project, design science was used to develop the design theory. The design theory (MPDP) was developed using the design process proposed by Walls et al. (1992). The kernel theories underlying the MPDP design theory are multiple perspectives approach and dialectic theory. Action research and system development research methods were used to validate and test the design theory. The action research project was implemented in the planning department of Orange County, Florida. Following the system development methodology, the researcher developed a decision support system prototype for zoning decisions using the MPDP design theory. Zoning decisions affect many factors including the environment, as development or re-development may have large impacts on ecosystems and the quality of life of both humans and other species inhabiting the area. Five stakeholder groups were identified in this project, one of them being environmentalists, who take an active role in zoning decisions. The final prototype was well accepted by the planning department staff and the different stakeholder groups involved in this action research project. This showed that the design theory proposed is feasible and applicable to complex decisions such as zoning decisions.

As illustrated by the DAGS framework, the contributions of this research project are both theoretical and practical. The project resulted in a design theory, the MPDP methodology, which serves as a guide for developers and systems designers of DSS in contentious situations and a DSS prototype for zoning decisions, which may have important environmental impacts.

CONCLUSION

Decision support for environmental issues involves both theoretical and applied elements. The DAGS framework provides a vehicle for incorporating existing theory into EDSS or for the development of new theory where needed, and instantiating that theory into systems to support the analysis of environmental issues.

With the continual introduction of new information technologies into many different areas of society there needs to be new research methods - methodologies and theories that will unearth new knowledge about IS, DSS and their effects on decision makers. Given ITs rapid evolution and growth the most effective way of studying and understanding this growth is through diversity. However, as IS researchers we need to be aware of the threat diversity poses and it is our responsibility to ensure that we are disciplined in our aims, and our choice of theory and research methods.

The need for collaboration with our colleagues within the academic and business communities is essential to fulfilling the promise of relevance in information systems research. What's needed is a change in the current IS research models. The DAGS framework is a multimethodical approach to IS research which offers a prescription in fulfilling the promise of relevance in IS research. Using this framework IS researchers can contribute to both theory and practice. Thus achieving relevance in IS research without compromising rigor.

Academics and practitioners have to become part of the same community so that the information gained from research becomes readily available to the practitioner. Conversely, when the research results find its way into practice, the practitioner needs to provide the researcher with feedback for evaluation and further study where appropriate. As an applied discipline, the adoption of the DAGS framework as a multi-methodical approach to IS system development by more information systems researchers will allow the discipline to make significant contribution to the practice of information systems, and in doing so help to foster the appropriate application and use of that information in business practices and governmental policies, especially those that have an environmental impact. .

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