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Towards an interactive process model for implementing IS innovation

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Abstract

Effective implementation of new information systems (IS) is a central concern of practitioners today. Research on IS innovation and implementation success factors has been considerable, however mixed and often conflicting results characterise the state of our knowledge. This paper reviews the literature concerned with IS innovation implementation to identify major concepts and key issues requiring attention. Three inter-related concepts are identified in the literature - complexity, uncertainty and knowledge dynamics - that have not been considered as interacting processes in any previous work identified. An interactive process model relating these three concepts is proposed to address this gap, and in doing so provides a way for the implementation process for IS innovation to be better understood.

Keywords

Innovation, IS Implementation, Process Models

INTRODUCTION

Organisations today make extensive use of new technology, and new information systems in particular, to improve performance. Yet frequent and major difficulties during and beyond implementation are still commonplace (Holahan, Aronson, Jurkat and Schoorman 2004; Klein, Conn and Sorra 2001). Therefore further research is needed to help organisations better understand the process of implementing complex new technology.

Research concerning new technology use in organisations has produced a diversity of theories and research models (Fichman 2000; Gopalakrishnan and Damanpour 1997). The existence of such diversity suggests that there are significant opportunities for building upon and synthesising previous work. This may lead to more generalisable and useful theory for researchers and frameworks for practitioners. As new insights emerge from the literature, they need to be reconciled with current knowledge, represented, empirically tested, and incorporated back into the knowledge base for guiding the practical use of technological innovation in organisations.

Researchers have argued that new approaches are needed to deepen our knowledge about how organisation-level mechanisms operate IS during innovation, especially where time is an important dimension of study (Slappendel 1996; Wolfe 1994). In a meta-analysis of previous IS diffusion research, Kautz, Henriksen, Breer-Mortensen and Poulson (2005) identified a lack of focus on conceptual and theoretical work, particularly in the interpretive research tradition.

Although there is previous theoretical (Attewell 1992) and empirical (Fichman and Kemerer 1997) research on the dynamics of knowledge acquisition during IS innovation, the questions of how these processes occur are still open. It is not well-understood how organisations facilitate knowledge acquisition during implementation, or how such knowledge can be used effectively (Fichman 2000).

This paper frames IS innovation implementation as a social process of mutual adaptation between technology and organisation (Leonard-Barton 1988). A conceptual process model is developed from the literature to integrate concepts identified as pertinent to knowledge acquisition during innovation of complex IS innovations.

We refer to this cluster of knowledge-related processes collectively as "knowledge dynamics." Our analysis of the literature suggests that complexity and uncertainty are important influences to be captured in a representation of knowledge dynamics during IS innovation implementation. While relationships between these concepts have been examined, we found no research that integrates them. For us this means there is a need to integrate the relationships to provide a more holistic view of IS innovation implementation.

We propose an interactive process model for learning more about how knowledge-related processes operate with respect to uncertainty and complexity. In knowledge dynamics, we focus on the processes of knowledge acquisition through individual signalling, organisational learning, and overcoming knowledge barriers. Individual signalling and organisational learning have both been identified by previous research as important, yet competing explanations for how knowledge about innovation is acquired - we consider both as potential contributors. Previous research suggests that knowledge barriers can be significant constraint to knowledge acquisition efforts and therefore should not be ignored. We offer this model to improve our understanding in the research and practice of implementing complex new information systems in organisations.

IS INNOVATION

Information Systems (IS) innovation is considered in this paper to be closely related to both technological and organisational areas of innovation research. The organisational branch both defines the context as the organisation and positions the type of innovation as being a novel idea of significant collective effort and duration to implement (Van de Ven, Polley, Garud and Venkataraman 1999). It specifically excludes consumer-oriented and individual-use innovations such as fax machines. The technological branch defines the type of innovation as being that realised through the application of new technology or existing technology to be used in new ways, in a social context (Tornatzky and Fleischer 1990). It specifically excludes innovations of a purely administrative or strategic nature such as total quality management.

IS innovation is defined in this paper to be the new application of technology in the social context of an organisation. Swanson (1994) (p.1072) defined IS innovation as "*innovation in the organisational application of digital computer and communication technologies (now commonly known as information technology, or IT).*" Swanson (1994) identified the set of relevant technologies to be computer and communication technologies, and the level of analysis to be the organisation.

IMPLEMENTATION

Innovation implementation is defined in this paper as "*all of the events, actions and decisions involved in putting an innovation into use*" (Rogers 1995) (p.403). Implementation has received attention as a research area due to the difficulties organisations experience during the implementation process. While progress has been made on understanding IS innovation processes in recent years, research on implementation in particular has been criticised for being highly fragmented and lacking integration (Fichman 2000; Klein and Sorra 1996; Kwon and Zmud 1987; Tornatzky, et al. 1990).

The study of implementation for IS innovation is important because the expected benefits of an innovation can be greatly influenced by decisions and choices made during implementation. IS use is not only dependent on system structures, but is also related to choices made by people using the system in a social context (DeSanctis and Poole 1994). Implementers make many assumptions and decisions about use during the implementation process for an IS innovation. Dysfunctional adaptations of an IS innovation can result from incorrect or inadequate knowledge of user practices. Conversely, dysfunctional adaptation of user environments can occur as a result of incorrect or inadequate use of the IS innovation. These dysfunctional adaptations lead to a loss of potential benefits available from use of the IS innovation (Davern and Wilkin 2004).

It has been observed that research studies often adopt narrow perspective regarding influences on implementation outcomes (Kwon, et al. 1987; Wolfe 1994). This provides a motivation for critically evaluating existing work, and seeking to ensure that important influences are not being ignored. Based on a review of the literature, an important cluster of such influences –complexity, uncertainty and knowledge dynamics – was identified. Researchers have examined these constructs and hypothesised relationships between them (Attewell 1992; Fichman, et al. 1997; Gerwin 1988; Rogers 1995; Tornatzky, et al. 1990), but no model of implementation could be found that brings them together with all the possible interactions represented and explained. The literature describing each of these concepts and how they may be related will now be discussed with reference to the proposed model.

THE INTERACTIVE MODEL

An interactive process model has been developed with three inter-related processes of complexity, uncertainty and knowledge dynamics. Knowledge dynamics are further specified in terms of different knowledge acquisition processes and related knowledge barriers. The linkages between concepts take the form of two-way feedback relationships. This is to emphasise the interdependence of concepts whereby a change in the state of one concept may initially be a cause but subsequently an effect through a feedback loop. For example, uncertainty motivates knowledge acquisition, which subsequently reduces the uncertainty. This has not been adequately represented in previous models of IS innovation implementation, although it is acknowledged that feedback loops are a central concept in innovation processes (Poole and Van de Ven 2004, p.65). The following sections build up the model through a discussion of the central concepts and relationships drawn from various sources of previous literature.

Uncertainty

Uncertainty is defined here as the existence of incomplete, unreliable or inconsistent information on goals, alternatives and consequences of an IS innovation (Gerwin 1988). Researchers argue that uncertainty is an important consideration in models seeking to explain cause-effect relationships in models of innovation (Gerwin 1988; Rogers 1995). Gerwin (1988) argued that the management of uncertainty during all stages of the technological innovation process is a key influence on the ultimate success or failure of the innovation.

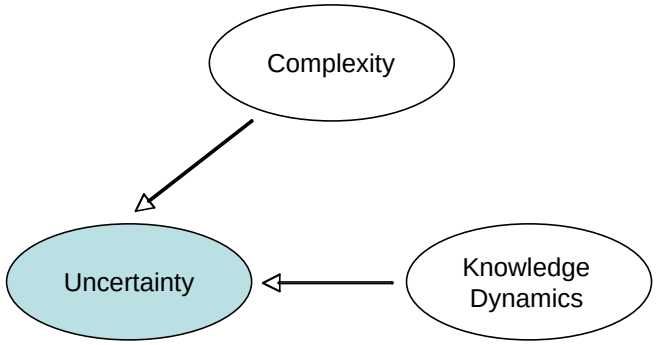

Figure 1: Influences on uncertainty

Complexity has been identified as a cause of organisational uncertainty in the literature. In implementation, uncertainty about measures used to assess an IS innovation's performance are influenced by technical complexity in the innovation (Gerwin 1988). That is, the complexity reduces an organisation's ability to define what constitutes 'good' performance and therefore reduces its ability to judge a particular performance as good or otherwise.

The important role of knowledge and the difficulty in overcoming barriers to gaining that knowledge, are considered distinguishing characteristics of innovation with complex information technology (Attewell 1992; Fichman, et al. 1997; Rogers 1995). Knowledge dynamics could be expected to have both positive and negative effects on uncertainty. On the one hand, knowledge acquired from communication sources with similar experiences, or through an organisation's own trial-and-error processes could provide valuable insights to reduce uncertainty. While the methods by which this knowledge can be acquired are not well known, one approach is to engage in cycles of mutual adaptation by reinvention of the IS innovation and restructuring the organisation during the implementation process (Leonard-Barton 1988; Rogers 1995). Reinvention is the process where implementers modify an innovation to better fit the organisation's implementation environment. Restructuring is where organisational structures are modified to better accommodate the innovation. These mutual adaptation cycles generate new knowledge about the innovation to reduce uncertainty (Leonard-Barton 1988).

On the other hand, information acquired from multiple external sources (versus information acquired through first-hand learning by the organisation) could be highly inconsistent, thus increasing the uncertainty about innovation alternatives and consequences. An organisation with members participating in diverse and active communication networks passing on information from similar but not identical prior implementation contexts makes inconsistency a highly probable scenario. The phenomenon of mutual adaptation between an organisation and innovation during the implementation process supports this argument, as no two adaptation processes are identical.

Complexity

Complexity in IS innovation has been recognised as a problem for organisations (DeSanctis, et al. 1994; Gerwin 1988; Rogers 1995). A simple definition of the complexity of an innovation is "*the degree to which it is perceived to be difficult to understand and use*" (Rogers 1995, p.16). Although useful, this definition is incomplete in that it does not consider complexity that can arise from the organisation or the implementation process. Complexity has been observed not only in relation to the nature of the innovation itself (Tornatzky, et al. 1990), but also the relationship between the innovation and the organisational context in which it is being implemented (DeSanctis, et al. 1994), and the implementation process (Leonard-Barton 1988).

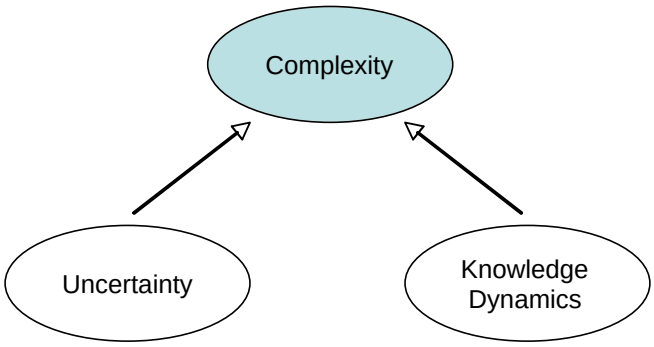

Figure 2: Influences on complexity

The definition above conceptualises complexity as perceived relative to the innovating organisation. The degree to which an IS innovation is perceived to be difficult to understand and use will be influenced by the effectiveness of knowledge dynamics in the organisation. In a seminal article Cohen and Levinthal (1990) advanced the concept of absorptive capacity to describe an organisation's ability to exploit new external information for commercial ends. The authors argued that absorptive capacity is a prerequisite for innovative performance, and that absorptive capacity is largely a function of an organisation's prior related knowledge, with diversity of knowledge also playing an important role. Fichman and Kemerer (1997) studied the use of software process innovations and confirmed these relationships, finding that existing related knowledge, and the level of diversity of technical knowledge an organisation are important factors contributing to effective knowledge dynamics in organisations implementing IS innovations. In addition, Fichman and Kemerer identified learning-related scale to be important. While Fichman and Kemerer did not use the term 'knowledge dynamics', they investigated organisational learning and learning barriers in their analysis, which will be shown to form key elements of knowledge dynamics in the next section. The process of mutual adaptation described earlier can also reduce complexity by simplifying elements of the innovation and/or the implementation context of the organisation.

Uncertainty about innovation has been observed to contribute to complexity in the implementing organisation and of the implementation process. Scudder et al. (1989) researched the implementation of a large and complex weapons system for the U.S. Navy. The researchers found that uncertain technical requirements were typically responded to by creating new specialised units, task forces and problem-solving teams that had the structural effects of increasing specialisation (a form of complexity) in the organisation.

Knowledge dynamics

Knowledge about how to implement and use a complex IS innovation is considered a critical determinant of implementation effectiveness. The high degree of knowledge required, and the difficulty in overcoming barriers to gaining that knowledge are distinguishing characteristics of innovation with complex information technology (Attewell 1992; Fichman, et al. 1997; Rogers 1995). These interacting processes all contributing to knowledge acquisition are termed 'knowledge dynamics' for the purpose of this model and will be elaborated in the next section.

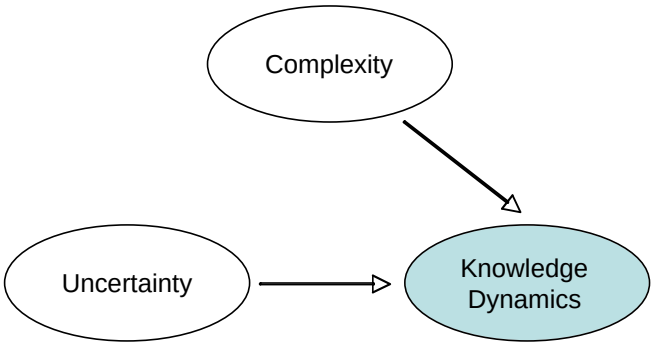

Figure 3: Influences on knowledge dynamics

Uncertainty exists when there is incomplete, unreliable or inconsistent information. The existence of uncertainty motivates innovating organisations to seek new information through communication networks (Rogers 1995) and acquire new knowledge through organisational learning (Attewell 1992). Rogers (1995) emphasised the importance of acquiring appropriate kinds of knowledge such as

awareness-knowledge, how-to knowledge and principles knowledge (Rogers 1995) in order to reduce uncertainty about an innovation.

An organisation also requires new knowledge in response to complexity in an IS innovation. Innovation complexity creates a need for more sophisticated technical infrastructure and support systems in the implementing organisation (Gerwin 1988). Increased knowledge and specialisation of staff is required to maintain the infrastructure and support the innovation. Complexity can reduce an innovation's performance once implemented as a result of the innovation requiring more sophisticated technical infrastructure and support systems than expected.

Rogers (1995) classified knowledge required for innovation into 3 types - awareness-knowledge (e.g. 'what is the innovation?' and 'what does the innovation do?'), how-to knowledge (e.g. 'how does the innovation work?' and 'how do I use the innovation?') and principles-knowledge (e.g. 'why does the innovation work?'). In his framework, Rogers (1995) omitted to recognise the importance of how-to knowledge about the implementation of an innovation. However, in the case of complex IS innovation the amount of how-to knowledge needed for implementation is much greater than in the case of less complex ideas. This is another way in which complexity influences knowledge requirements. Rogers (1995) framework assumes knowledge to be readily communicable and available through communication networks, an assumption not shared by all innovation researchers. The model proposed in this paper considers not only communication networks, but also organisational learning as processes of knowledge dynamics. This will now be examined in more detail.

Inside "knowledge dynamics"

There is a divergence of opinion about how knowledge is acquired in the implementation of complex IS innovation. One view is that knowledge needed by organisations is acquired primarily from a flow of information via mass media and through *communication networks* between individuals (Rogers 1995). The innovation diffusion process is the communication of a new idea from one individual to one or more others (Rogers 1995). This may be via mass media channels or interpersonal channels involving communication networks. In our context the latter channel involving face-to-face exchanges between individuals is most relevant. The other view is that the information needed to implement and use complex new technology for is essentially non-transferrable and must be acquired in a process of *organisational learning*. Information provides a basis for knowledge acquisition via new institutions which exploit a need for certain technical knowledge about innovations (Attewell 1992).

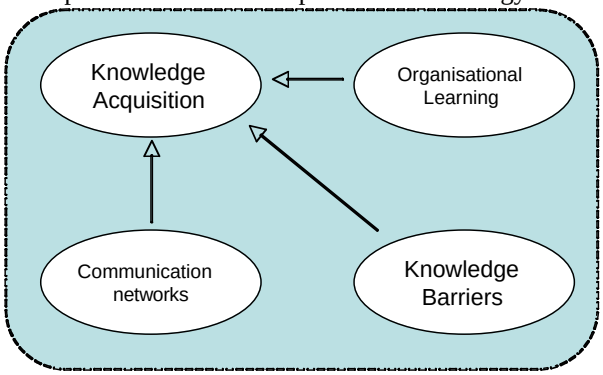

Figure 4: Inside knowledge dynamics

Attewell (1992) further argued that the existence of *knowledge barriers* is a distinguishing feature of complex new technology (and by extension information systems). Such technology requires a high degree of knowledge and skill to effectively implement and use. This results in knowledge barriers, and produces a requirement on adopters to engage in organisational learning in order to implement them. Attewell highlighted a perceived gap in Rogers' (1995) theory whereby, through communication networks, missing knowledge is 'transferred' to an organisation in need of it. Instead, Attewell (1992) argues that only information can be transferred, knowledge must instead be created through organisational learning and this can be difficult to achieve due to various barriers. However, Attewell (1992) does not explain the dynamics of how knowledge is created at the organisational level.

Fichman and Kemerer (1997) found support for Attewell's (1992) argument in an investigation of object oriented programming languages used by organisations. When asking what makes some organisations less adversely affected by knowledge barriers than others, the study found that organisations that effectively lowered knowledge barriers had greater success in adopting technological innovations. This research did not focus on implementation but rather considered the whole innovation use process. Innovation stage reached was used to measure the degree of success and thus the level of knowledge barriers present. However, the research leaves open the question of how knowledge barriers were reduced by these factors to enable effective knowledge acquisition.

In later work, Fichman (2000) identified a need for researchers to further investigate mechanisms that actively lower knowledge barriers over time, and to explore the correlation between organisational learning requirements and technological innovation. The research identified questions requiring further investigation, such as how organisations can facilitate knowledge acquisition during implementation, and how such knowledge can be used

effectively. This paper argues that both organisational learning and communication network processes enable knowledge acquisition, and that complexity and uncertainty are also central concepts to be considered in answer to these questions.

The organisational learning literature investigates how organisations create, retain and transfer knowledge (Argote, McEvily and Reagans 2003). A focus of our research is how an organisation acquires innovation knowledge to manage uncertainty and complexity in implementation. Nonaka and Takeuchi (1995) developed a theory of organisational knowledge creation and knowledge transfer. They make several criticisms of the way in which conventional theories conceptualise knowledge and organisational learning, in order to better explain the processes of technological innovation.

Firstly, most innovation theories address only the level of 'explicit' knowledge – that is, knowledge that can be codified and communicated in formal systematic language. Tacit knowledge, which is personal and highly context specific, is not considered. However, much of the innovation literature stresses the importance of context in making choices and decisions about how to navigate the innovation process (Tornatzky, et al. 1990). Secondly, the theories investigate only mechanisms of searching for and obtaining existing knowledge. Processes of creating new knowledge are not considered. Finally, there are no investigations of how organisations convert knowledge from their experience into useable and communicable forms for effective transfer to others.

The theory proposed by Nonaka and Takeuchi (1995) identifies two kinds of knowledge, explicit and tacit, and four modes of knowledge conversion, socialisation, externalisation, internalisation. During the implementation of IS innovation, the processes of knowledge creation, and conversion from one form to another for knowledge transfer, could be very important to implementation success. However, there is little research from the innovation literature that has considered this.

The theory presents knowledge creation and knowledge transfer as intimately linked and dependent on each other. This is consistent with arguments made by Attewell (1992) that the 'knowledge transfer' traditionally conceptualised by innovation studies in the form of individual communication, is superficial. Attewell argues that knowledge transfer for innovation implementation involves much deeper processes of creating new knowledge from detailed technical and procedural information provided by supply-side organisations in the innovation user's environment.

The Complete Interactive Process Model

The complete process model shown below highlights the three interactive processes of complexity, uncertainty and knowledge dynamics in the implementation process. Knowledge dynamics is further specified in the sub-processes driving knowledge acquisition - communication networks and organisational learning, including the process of overcoming knowledge barriers.

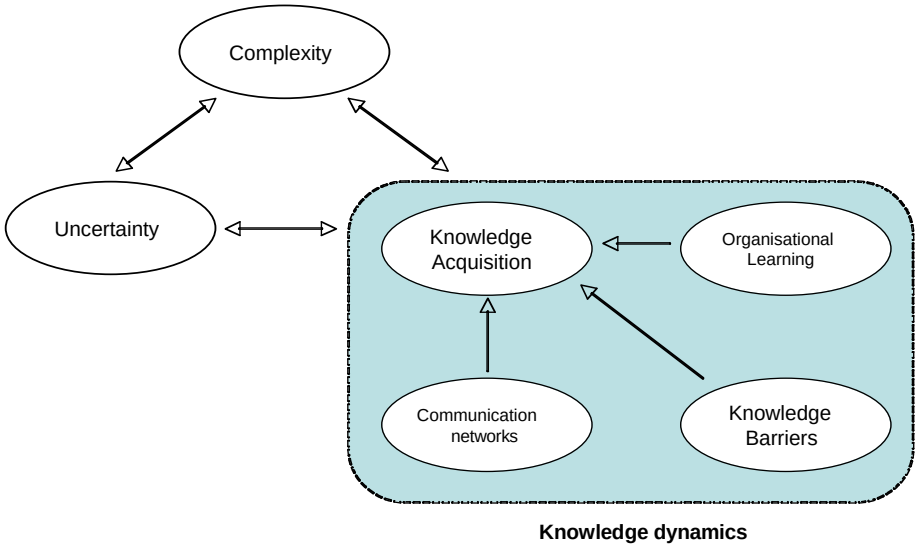

Figure 5: The complete process model

The analysis of uncertainty, complexity and knowledge dynamics in the preceding sections illustrates that when taken in sum, each process can influence all the others. All three relationships are two-way relationships that may change in strength and direction over time. A better understanding of the dynamic nature of these relationships can help practitioners by recognising the interdependencies and thus the effects of implementation actions and decisions. For example, in seeking to reduce technical complexity, new uncertainty may be generated, and new knowledge will need to be acquired. This may in turn increase complexity in another part of the organisation.

Based on a survey of previous literature, we have described using the above model, how uncertainty in IS innovation, complexity in the innovation or organisational context, and knowledge about IS innovation interact to influence each of the other processes during the implementation process. By focusing on knowledge acquisition during the implementation process, this model seeks to improve our understanding of mechanisms for overcoming knowledge barriers by considering both communication networks and organisational learning processes.

CONCLUSION AND FUTURE RESEARCH

This paper has developed a model to assist researchers and practitioners in understanding that the process of acquiring new knowledge about complex IS innovations can influence and be influenced by both uncertainty and complexity in the innovation, the organisation and the implementation process. In IS implementation the relationships are reciprocal and feedback occurs - making the relationship between concepts interactive.

As a next step, the proposed model needs to be tested in an empirical study. We are pursuing this in the context of an implementation of electronic health records at a large Australian healthcare organisation. The electronic health record is a longitudinal collection of personal health information, usually based on an individual, entered or accepted by healthcare providers, that can then be distributed over a number of sites or aggregated at a particular point. The information must be organized to support continuing, efficient and quality healthcare.

For the Australian health sector, this is an innovation involving significant complexity and uncertainty. The project needs to coordinate with related initiatives by other stakeholders in public and private sector healthcare, and integrate many diverse information sources from providers such as GPs, hospitals and medical laboratories. The first stage of the implementation is a pilot project with several thousand consumers due in October 2005, with a full-scale implementation involving seven million consumers to follow. In the light of the complexity and related uncertainty of this endeavour, knowledge acquisition during the IS innovation implementation process for the pilot project will be a critical to subsequent effectiveness of the full-scale implementation. It is hoped that the proposed interactive model will be of value in understanding and thus aiding the process of implementation.

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