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The labour of learning: a framework for understanding knowledge barriers in IT innovation

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Abstract

In recent years the metaphor of knowledge barriers in organisational learning has gained currency to help analyse and explain innovation with complex information technology (IT) in organisations. Despite ongoing research, it is argued that the central concept of a 'knowledge barrier' remains under-conceptualised. It is important to address this gap to further our understanding of IT innovation processes in organisations. This paper proposes a framework that clarifies the concept of a knowledge barrier, and integrates two research approaches to explain sources of knowledge barriers. Support for the model is provided using a case study of complex technology innovation in the Australian healthcare sector.

Keywords

Technological innovation, organisational learning, knowledge barriers

INTRODUCTION

The concept of knowledge barriers has been useful in advancing our understanding of innovation involving complex information technology (IT). Unlike other forms of innovation, significant technical know-how is required to both implement and use complex IT in organisations. Organisations wishing to exploit complex IT need not only the will, but also the knowledge to do so. This is because implementation of complex IT typically requires substantial changes in both the technology and the organisation, changes that can only be learned through experience. Acquiring new technical know-how is not a simple process of communication or information transfer, but a slow and difficult process of organisational learning.

Our current conceptualisation of knowledge barriers needs to be developed if we are to clearly distinguish them from other kinds of problems in innovation and understand whether they are a homogeneous concept or something more diverse. Organisations must also be able to recognise knowledge barriers and how they develop if they are to respond effectively in their efforts to implement and use complex IT. Relative to the rapid growth of research on organisational learning in IT innovation, there has been little exploration of the role played by knowledge barriers. Research investigating knowledge barrier types, causes and actions for overcoming them at a general level exists, but is fragmented (Robey et al. 2000). Efforts to clearly define what knowledge barriers are, how they arise and how they are overcome are less well advanced. As a result, the concept of knowledge barriers remains underdeveloped.

This paper proceeds by examining the nature of knowledge and how it relates to the concept of a knowledge barrier. Previous research on knowledge barriers and organisational learning are critiqued. A definition, framework and a process model are developed to clarify and deepen our theoretical understanding of knowledge barriers. We use a case study of complex IT implementation in a healthcare context to make some preliminary validation of the model.

KNOWLEDGE

Knowledge is a concept with many meanings, and the purpose of this section is to draw attention to those aspects of knowledge pertinent to an investigation of knowledge barriers. There is a critical distinction between knowing 'that' something exists, and knowing 'how' it operates (Ryle 1949). These two forms of knowledge are also known as propositional or declarative knowledge - for 'knowing that' - and technical or procedural, knowledge - for 'knowing how' (OED 1989; Nonaka 1994).

A slightly different distinction has been made between explicit knowledge and tacit knowledge (Polanyi 1967; Nonaka 1994). Explicit knowledge can be codified and transmitted in formal, systematic language. Tacit knowledge cannot be codified and can only be gained through personal experience. It is highly contextual and cannot be transferred in the sense that explicit knowledge can be transferred.

Clearly there are similarities between the propositional-technical dimension and the explicit-tacit one, although they are not mutually exclusive. It is possible that some portion of technical knowledge could exist both explicitly, for example as documented procedures for installing and configuring a complex software system, and tacitly, as the skills and contextual awareness possessed by an experienced professional in following, and improvising, the procedures. The important point is that technical knowledge tends to have a high tacit component relative to propositional knowledge, and tacit knowledge requires greater effort to learn than explicit knowledge. This explains why the literature that investigates knowledge barriers in technology innovation focuses on technical knowledge as a source of barriers.

KNOWLEDGE BARRIERS

Attewell (1992) argued persuasively that technical knowledge cannot easily be transferred between people, but must be acquired through a process of learning and skill formation. This process is often burdensome and consequently presents barriers to adoption of complex technology. The first two elements of Attewell's knowledge barrier perspective on innovation diffusion assert that "organisational learning is partly a consequence of the immobility of technical knowledge," and that "the burden of developing technical know-how (organisational learning) becomes a hurdle to adoption" (p.7). Other than the above statements, Attewell did not directly define knowledge barriers, but drew on the metaphors of 'knowledge burden' and subsequent 'hurdle to adoption' to describe them. Restating these ideas for the purpose of critical examination, a knowledge barrier is therefore "a hurdle faced by an organisation due to the burden of developing technical know-how needed to adopt an innovation." Three suggestions for improving on this description are made.

Firstly, usage relies on extensive use of metaphors, providing ample opportunity for divergent interpretations. The burden[1] is a metaphor for the effort of labour required to develop technical knowledge through organisational learning. The hurdle[2] is a metaphor for the effect of this burden as an obstruction to the innovation adoption process. Thus, a knowledge barrier is a metaphor for a hypothesised causal relationship between the labour of developing technical knowledge through a process of organisational learning and the probability of not adopting an innovation. The greater the effort of labour required, or perceived to be required, the less likely that adoption proceed. On one hand, the ability to reduce the complexity of concepts and relationships above through the use of metaphor is a strength of the description. Further, metaphor is a valuable tool in the development of new ideas (Nonaka 1994). However, there is potential for inconsistent interpretations and resulting confusion with so much not made explicit. A more literal explanation that both exploits any new understandings and reduces the reliance on metaphors would improve consistency of interpretation and provide a richer notion of the concept for further study.

Secondly, although the context of the description is technology adoption, it is relevant through the whole innovation process. Knowledge barriers have been investigated in different stages of technology use (Fichman and Kemerer 1997b), longitudinally through diffusion (Tanriverdi and Iacono 1999), and in implementation specifically (Robey et al. 2002). A description of knowledge barriers in the broader innovation context would provide a nexus for several avenues of research.

Thirdly, while knowledge development is a critical part of organisational learning, it should be acknowledged that this is a general term for several organisational learning processes such as knowledge discovery (Snyder and Cummings 1998), distribution (Huber 1991) and interpretation (Leavitt and March 1988). A more finely-grained consideration of the sub-processes that may give rise to knowledge barriers is needed. Further, a range of antecedent conditions to organisational learning such as knowledge ambiguity (Simonin 1999) and organisational absorptive capacity (Cohen and Levinthal 1990) have also been linked to an organisation's learning abilities. These different approaches are discussed below. A broader consideration of the organisational learning process, its antecedents and outcomes would improve our understanding of how knowledge barriers arise. Organisations can be more effective in overcome knowledge barriers by addressing causes as well as symptoms.

In summary, the original conception of a knowledge barrier leaves much open to interpretation, was explored only in an innovation adoption context, and recognised the organisational learning process only in general terms as a source of knowledge barriers. Before attempting to construct a definition addressing these limitations, previous research on known causes of knowledge barriers and actions that organisations can take to overcome them in IT innovation is reviewed. Two approaches to overcoming knowledge barriers are evident from the literature on organisational learning and innovation. One approach looks at antecedents to gaining technical knowledge and how these can be influenced, while the other looks at problems in learning processes and how they can be addressed. Both perspectives contribute to a more holistic view of the conditions and actions that

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[1] "Burden," (OED 1989), Def. 2. a. fig. A load of labour, duty, responsibility.
[2] "Hurdle," (OED 1989), Def. 1. e. fig. An obstacle or difficulty.

produce knowledge barriers, and therefore both should be considered in further developing the construct (Robey et al. 2000).

Antecedents to gaining technical knowledge

Researchers have empirically examined factors to explain organisational learning and technical knowledge development within an innovating organisation from a range of different perspectives. These include the exploitation of external knowledge (Cohen and Levinthal 1990), the creation of new internal knowledge (Fichman and Kemerer 1997b), knowledge transfer in strategic alliances (Simonin 1999) and transfer of best practices within an organisation (Szulanski 1996). This synthesis yields a set of antecedent characteristics to organisational learning that influence outcome of gaining new technical knowledge. A summary of empirically significant characteristics reported by these studies is presented in Table 1, with the dependent variable described as 'difficulty of gaining technical knowledge' and the effect of independent factors expressed with reference to this difficulty. The implication is that each of these characteristics can also be interpreted as a root cause of knowledge barriers in an innovation context. This will be elaborated with reference to the model proposed later.

Factor	**Cohen (1990)**	**Szulanksi (1996)**	**Fichman (1997)**	**Simonin (1999)**
Knowledge ambiguity (+)		Yes		Yes
Knowledge tacitness (+)				Yes
Knowledge complexity (+)				Yes
Prior related knowledge (-)	Yes	Yes	Yes	Yes
Diversity of knowledge (-)	Yes		Yes	
Learning-related scale (-)			Yes	
Relationship with source[3] (-)		Yes		Yes

Table 1: Previous empirical support for factors influencing difficulty of gaining technical knowledge

The more ambiguous, tacit and complex the knowledge being sought, the more difficult it is for an organisation to acquire the knowledge. Ambiguity of knowledge is the difficulty in determining what caused a certain performance outcome from the application of certain knowledge or skills. Complexity of knowledge refers to the number of interdependent technologies, routines, individuals and resources linked to the knowledge. Tacitness, discussed earlier, is the degree to which knowledge is based in experience and cannot be easily codified. For organisations it has been shown that the less prior related knowledge, narrower diversity of knowledge, smaller learning-related scale, the more difficult it is acquire new knowledge. In situations where learning entails a relationship with another entity, the closeness or intimacy of relationship also affects the effort required to acquire the knowledge.

Implicitly, any actions that produce more favourable conditions for any of the factors above will benefit organisations facing knowledge barriers. Research has also identified a number of explicit recommended actions for reducing knowledge barriers. Actions available to a firm must be considered in the context of a broader innovation network of organisations. The network comprises parties other than the innovating organisation, such as technology producers, vendors and consultants. Participation by these organisations in knowledge creation is an important process by which an organisation can overcome knowledge barriers (Attewell 1992). This produces options including: seeking the technology as a service and avoiding the need for technical knowledge to implement and maintain it; employing the know-how of experienced consultants; taking advantage of improvements in automation and standardisation to hide complexity; participating in user groups; and using education services. However, in the early phase of a technology's diffusion, many of these actions are unlikely to be available to innovating organisations. They emerge over time, in the network of organisations with a stake in the technology. Therefore innovating organisations that adopt in the early stages of a technology's lifecycle will in general face a narrower range of action choices, and those actions will be less within their control. Other actions less dependent on an organisational network are investing in organisational learning for existing staff (e.g. through action research, situated learning, benchmarking) and adopting a simpler technology variant (Fichman and Kemerer 1997a; Robey et al. 2000).

Learning processes and problems

There have been many and varied attempts to describe the organisational learning process in detail. Far fewer efforts extend to an examination of both the organisational learning process and problems that can occur within

[3] *Relationship with source* is conceptualised as the opposite of 'arduous relationship' examined by Szulanski and the two factors of 'organisational distance' and 'cultural distance' examined by Simonin.

it. It is argued that these problems can provide insight into the emergence of knowledge barriers. Learning problems can give rise to knowledge barriers both directly, and by amplifying problems arising from antecedent characteristics presented in Table 1. While interpretations of both the organisational learning process and problems vary somewhat between researchers, there is significant commonality between findings from studies of problems in organisational learning, e.g. (Leavitt and March 1988; Huber 1991; Snyder and Cummings 1998). Table 2 shows a synthesis of these three interpretations of organisational learning processes. These processes do not necessarily occur in a linear fashion, but may interact and overlap. Table 3 summarises potential learning problems, indicating the organisational learning sub-process in which they are likely to occur.

This research	Snyder (1998)	Huber (1991)	Leavitt & March (1988)
Discovery	Discovery	Acquisition	Organisational Search
Acquisition	Invention	Acquisition	Experimentation, Transfer from others
Interpretation	Generalisation	Interpretation	Interpretation
Application	Production	Distribution	
Feedback	Feedback		
Maintenance		Organisational Memory	Organisational Memory

Table 2: Organisational learning processes/constructs

Discovery is the process of defining and setting innovation objectives and performance standards and comparing these with current outcomes (Snyder and Cummings 1998). Discovery involves interpretation and may result in identification of performance gaps that motivate subsequent processes such as further knowledge acquisition or knowledge application. It is a part of the organisational learning process that, in the real world, overlaps significantly with the 'innovation process'. *Acquisition* (Huber 1991) is the umbrella process of obtaining new knowledge. The two most widely recognised methods of obtaining knowledge are through direct experience and vicariously from the experience of others. Other methods such as inheritance and grafting (hiring new members with valued knowledge) have also been included in this concept, as has the discovery process although discovery is treated separated for the purpose of this paper. *Interpretation* is the process through which information is given meaning, events translated into shared understandings, and outcomes come to be classified as good or bad (Leavitt and March 1988; Huber 1991). *Application* is the process of enacting new knowledge through organisational action. It is closely analogous to the production concept of Snyder and Cummings (Snyder and Cummings 1998). An alternative view is that knowledge acquisition inextricably involves application of knowledge. While this is clearly the case for experimental 'learning-by-doing' the argument is less convincing for knowledge acquisition processes such as grafting and therefore has been represented separately here. *Feedback* is the process of making changes in antecedent conditions for future learning processes based on the outputs of a current process. Feedback can occur between any two processes as they all have some form of input and output. *Maintenance* is the process of storing and conserving knowledge in organisational memory, and retrieving it from organisational memory. Knowledge is maintained in the form of routines, which include "the forms, rules, procedures, conventions, strategies, and technologies around which organisations are constructed and through which they operate ... [and] the structure of beliefs, frameworks, paradigms, codes, cultures, and knowledge that buttress and contradict the formal routines" (Leavitt and March 1988, p.320).

It is problematic to represent these organisational learning sub-processes in a linear or even any time ordered sequence with one logically following another. In reality, they are happening multiply and simultaneously within any innovation context.

Process/Construct	Sources: (Leavitt and March 1988; Huber 1991; Snyder and Cummings 1998)
Discovery	• Obstruction or restriction of organisation scanning leading to failure to perceive opportunities or problems due to e.g. powerlessness, insufficient information, overconfidence.
Acquisition	• Deficiencies in the conceptual maps that organisational members use to guide, analyse and generate solutions. • Lack of coordination between multiple competing perspectives. • Rejection of new knowledge offering advantage due to early specialisation in inferior techniques (competency trap). • New learning rejected due to limits on the legitimacy of socialising agents (legitimacy trap). • Gaining the knowledge is a competitive threat to other organisations.
Interpretation	• Errors induced when the subjective experience of learning is compelling but links between actions and outcomes are invalid (superstitious learning).

Process/Construct	**Sources: (Leavitt and March 1988; Huber 1991; Snyder and Cummings 1998)**
	• Ill-fitting conceptual maps, paradigms, frames of reference and defence of these even given contradictory evidence; absence of double-loop learning. Can lead to escalation of commitment and/or scaling down of aspirations and goals. • Inability to monitor, document, encode experiences and share results. • Ambiguous or shifting measures of success preventing consistent evaluation of outcomes as successful or failed.
Application	• An inability to act on knowledge gained due to knowledge or contextual ambiguity, lack of consensus, actor complacency, information overload. • Disconnection between intentions and actions; lack of awareness of knowledge in other parts of the organisation due to ineffective routines or politics.
Feedback	• Distorted, suppressed or delayed feedback on results of action.
Maintenance	• Resource limits. Transforming learning into routines and artefacts consumes resources and has costs. Knowledge may not be codified into routines or artefacts due to cost or time constraints. • Loss of tacit knowledge maintained only in the experience and practices of individuals when the individuals depart.

Table 3: Synthesis of organisational learning processes and problems

Perhaps the most recognised work that addresses how to overcome organisational learning problems is Argyris and Schon's (1996) theory of organisational learning. The theory articulates two distinct levels of learning: instrumental or single-loop learning to detect and correct problems in organisational processes (e.g. implementing a technological innovation) and double-loop learning to detect and correct problems in the organisational learning process itself. Double-loop learning means learning that helps actors become aware of a problem and change their values and assumptions about how the organisational works - their 'organisational theory-in-use'. Feedback and correction on both levels is necessary to avoid or overcome problems such as those described in table 3.

This section has sought to develop two complementary sides to the story of knowledge barriers in IT innovation. On one hand research has identified a range of antecedent characteristics that can make it difficult to recognise, acquire and use new knowledge (Cohen and Levinthal 1990; Argyris and Schon 1996; Szulanski 1996; Simonin 1999). Literature has also identified related actions to modify these characteristics such that knowledge barriers should be reduced. On the other hand, there is a body of literature that has examined organisational learning processes in detail, identified numerous problems that can occur in those processes, and developed approaches for recognising and overcoming them (Leavitt and March 1988; Huber 1991; Argyris and Schon 1996; Snyder and Cummings 1998). Knowledge barriers arise due to both the raw materials of knowledge and the process of how new knowledge is created. A framework for bringing these two approaches to knowledge barriers together is presented in the next section.

PROPOSED FRAMEWORK

It is proposed here that by combining research on overcoming 'knowledge barriers' in the technology innovation process with that of overcoming problems in the organisational learning process, better explanations for how knowledge barriers arise can be made, leading to a more effective actions to overcome them. Actions will be more effective because they can address causes from both antecedent and process perspectives. In summarising the above discussion, the following definition and statements of a framework illustrated in Figure 1 are proposed:

> A knowledge barrier is defined here as *'an obstacle to action requiring technical knowledge in innovation, experienced by actors as a need for excessive resources in organisational learning.'*

A need for excessive resources in organisational learning can arise from antecedent characteristics of the knowledge needed, the actors involved, and an organisation's available resources (Figure 1, label 1). It can also arise independently from problems in organisational learning processes (Figure 1, label 2). Learning problems may also serve to make the impact of antecedent characteristics more severe. The ultimate impact of a knowledge barrier is to prevent or constrain the application of knowledge for action in ongoing innovation processes (Figure 1, label 3).

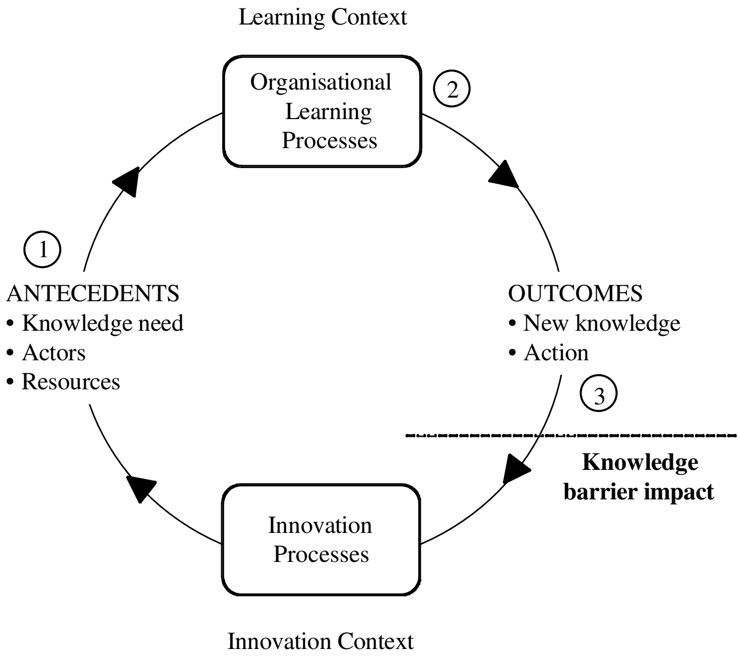

Figure 1: Knowledge barrier development framework in an innovation/learning cycle

Two independent action strategies are available to an organisation attempting to overcome knowledge barriers. Firstly, knowledge barriers can be overcome with actions that affect the antecedents to learning, e.g. reduce the amount of knowledge required, increase the time available, educate actors to increase related knowledge. The second action strategy is attempting to identify and correct any problems in organisational learning processes.

Antecedents

Knowledge barriers can arise due to antecedent conditions for organisational learning. As outlined earlier, numerous antecedent constructs have been hypothesised and empirically shown to raise barriers to knowledge transfer within and between organisations. *Actor* characteristics, where the learner may be an individual, group or a whole organisation, include related knowledge, diversity of knowledge learning-related scale and relationship to the source of knowledge (Cohen and Levinthal 1990; Szulanski 1996; Fichman and Kemerer 1997b; Simonin 1999). Characteristics of the *knowledge needed* include causal ambiguity, reliability, complexity, tacitness and specificity (Szulanski 1996; Simonin 1999). Other important *resources* determining the initial conditions for learning are time, personnel, and material - both physical artefacts and financial means (Clayton 1997). These have been added to the model although they were not explicitly considered by the studies summarised in Table 1.

Learning Processes

The framework in Figure 1 shows two major processes - the innovation process and the organisational learning process. In practice these processes are not distinct but overlap and intermingle. They have been represented separately here to clarify and highlight the emergence process for a knowledge barrier by casting organisational learning in the foreground, with the innovation process and context in the background. It is argued that the model is sufficiently generic for relevance at multiple levels of analysis - i.e. individual, group and organisational levels. The organisational learning sub-processes are discovery, acquisition, interpretation, application and maintenance. These were synthesised from previous research discussed and summarised in Table 2. Within these sub-processes, numerous learning problems such as competency traps and superstitious learning (refer to Table 3) can contribute to the labour of learning to produce knowledge barriers.

Learning Outcomes

The outcomes of organisational learning are new knowledge and action. These are inputs for the innovation processes, the outputs from which become the antecedents for future learning cycles. In the innovation context new knowledge is expressed through actions of human behaviour. It is acknowledged that action is not a required outcome to claim that organisational learning has occurred (Huber 1991), but it is argued that this only holds true when treating organisational learning in isolation from an innovation process that fuels it. Although knowledge outcomes and hence learning is possible in the absence of action, without action to observe and evaluate learning success or failure by, there is no feedback and no cycle of innovation and learning as illustrated in Figure 1. Such a situation could indicate a learning problem in application such as inability to act on knowledge, or a distortion of delayed or suppressed feedback.

CASE STUDY

The framework presented above is now used to explain the unfolding of a series of events involving knowledge barriers from a longitudinal case study at HealthCo, a pseudonym for a large Australian healthcare provider. Pertinent points from the discussion are summarised using the framework, shown below in Figure 2.

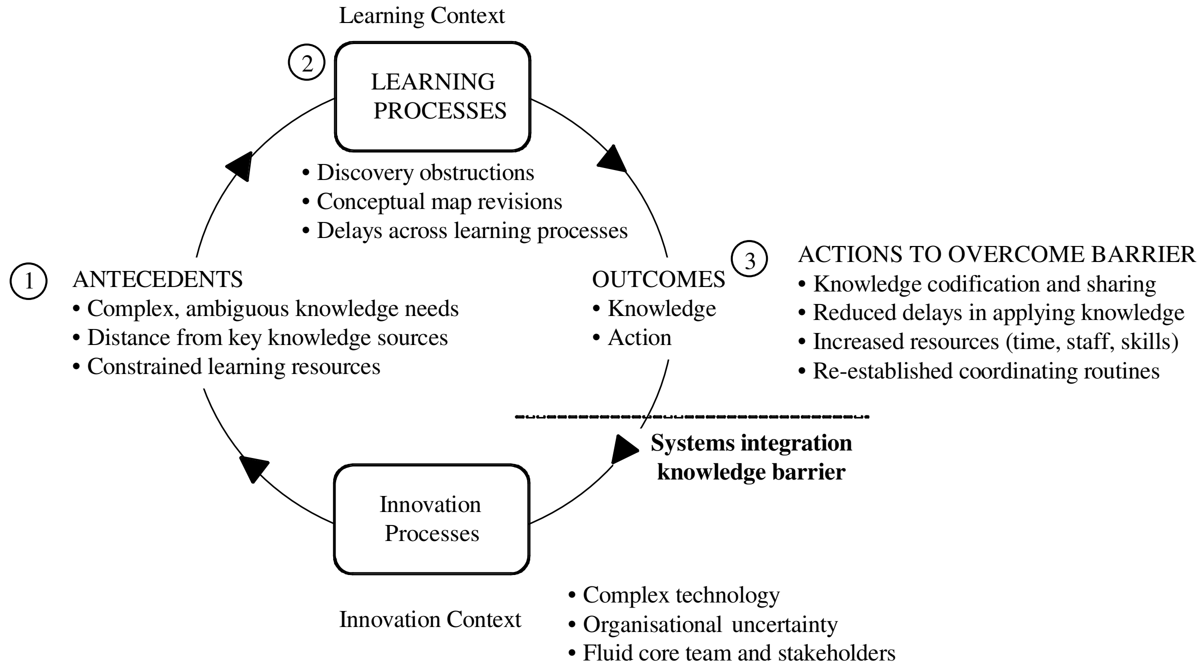

Figure 2: Knowledge barrier development framework applied to the HealthCo case

Method

The research method employed in the case study is interpretive. HealthCo innovation data was collected from multiple sources. A focus group with innovation team members was held early in the implementation, extensive case notes were made from meetings and ad-hoc interviews held over the duration of implementation, and a post-implementation survey was conducted. The main data source for this analysis was coded observations.

Observations were recorded during frequent attendance at project meetings and workshops over an 18 month period of on-site research at HealthCo. Current and historical documents were provided for later reference. A longitudinal series of 'incidents' was recorded during the observation period in a database. An incident was the researcher's interpretation of any substantive change in project direction based on a the predefined concepts of the innovation idea, people involved, resource transactions, actions taken and outcomes observed (Van de Ven et al. 1989). Each incident contained structured elements such as information source, a set of 'codes' and a single large descriptive item. The incidents were reviewed with a HealthCo representative periodically for feedback on accuracy and gaps. Several hundred incidents were recorded and later constructed into 'event sequences' by the researcher. These event sequences represented the unfolding of various threads of the project over time. Events that were interpreted to have some bearing on knowledge barriers were coded as such and analysed further.

The innovation context

The IT innovation is a clinical system for sharing medical information electronically (referred to henceforth as the SCS - shared clinical system). The information is under the control of the individual whilst being stored and maintained by the organisation. The core SCS technology is a software package that had been trialled previously in Australia and is in routine use by other countries. However, major components of the total system have been adapted or developed specifically for this innovation. For HealthCo, the implementation of this innovation represented a large undertaking and required constant efforts to learn new technical knowledge.

The HealthCo implementation team began with a sponsor plus 4 full-time staff, including the project manager. A vendor team consisting of 16 staff (not all full-time) from a software provider and systems integrator worked from a nearby location. For the first 9 months of the project HealthCo held regular bi-weekly progress meetings with the vendor team, who also provided regular status reports. This coincided with project milestones at the commencement of implementation that specified vendor customisation and testing to be complete after 12 months. Tasks such as compliance with privacy regulations, integration to hospital systems, unique identification of patients and developing new organisational procedures were the responsibility of the HealthCo team. The system launch was planned for the 13th month in two pilot locations.

In the 11th month of the implementation, a new program manager joined the HealthCo implementation team. The HealthCo team held a major project review. Following this they realised it would not be possible to launch in the 13th month and after further deliberation the launch date was moved an additional 5 months to the 18 month mark. Over the coming months several more staff were recruited to the project team. The new launch target was met, albeit in a configuration that was significantly different to that earlier envisaged. This innovation journey will now be explained from a knowledge barrier perspective.

While several examples of knowledge barriers emerged during the observation period, this case will focus on one barrier central to the innovation's development to demonstrate the validity of the framework. A critical element of the innovation was to work out how data about a person could be collected from many diverse sources (source systems), then reliably assembled into a single coherent view. This challenge grew progressively larger and more complicated as the team learned how to identify, prepare, test and verify the activation of each source system. What existed in the antecedent conditions, context and learning processes to explain how this knowledge barrier emerged? How did the organisation respond and how effective were their actions?

Learning context

After 8 months, an external shock in the form of an organisational restructure occurred. Although the timing of this event was known, its impact was not fully appreciated until some time afterwards. HealthCo was split into two separate entities and this also split the HealthCo innovation project team into two groups - strategy and implementation. The following two months were turbulent as the HealthCo innovation team and the organisation adjusted to the new configuration.

Antecedents

This section considers characteristics of the actors, the knowledge needed, and the resources available to the innovation unit. HealthCo team members were familiar with most of the hospital-based source systems and expert in some, but possessed no technical knowledge about how messages from these systems would be integrated into the SCS. The vendor team possessed expert knowledge about how to integrate data feeds into the SCS but they had minimal knowledge of the source system implementations at HealthCo. The vendor and HealthCo teams worked at physically separate locations. HealthCo retained a contractor in health data standards for expert knowledge, however he had little interaction with the HealthCo or vendor teams. A separate HealthCo project was developing a service for uniquely identifying individuals using the SCS. Knowledge of how this service worked was critical to the SCS team, but the relationship between the two groups was distant.

The technical knowledge to integrate and make ready source system data feeds for the SCS demonstrated many characteristics indicating that it would take a great deal of effort to learn. It was highly complex, with many interrelated elements - privacy regulations, messaging standards, the core SCS system, many source systems, and a yet-to-be-developed identification system were prominent examples. It also presented a high level of knowledge ambiguity. These key antecedent factors alone highlighted the importance of close working partnerships between the various owners of partial knowledge (Simonin 1999). Much of the knowledge required appeared to be explicit in nature, however it became evident later in the project that a great deal of tacit knowledge was required to represent the standards, rules and regulations in the system.

Personnel resourcing was initially limited at HealthCo with only 5 dedicated staff in the early stages of the implementation process. This did yield evidence of knowledge barriers as implementation progressed, and will be discussed in the next section. The vendor team began with 16 people indicating a large learning-related scale. It proved very difficult later on to alter HealthCo staff resourcing, and easier to alter vendor staff resourcing. This reduced the ease with which organisational learning could be codified and shared at HealthCo. Financial resources, while limited, did not appear to present obstacles. One of the reasons for the separate vendor and HealthCo teams was a resource constraint on space at HealthCo's offices.

Learning processes

This section highlights from the case indications of problems in organisational learning sub-processes presented in Tables 2 and 3. The external shock of a restructure at HealthCo in the 8th month disrupted learning processes for several months. It was possible to identify problems across all learning sub-processes from Table 3. For example, members of the innovation team expressed feelings of isolation and confusion about current activities that compromised interpretation, application and feedback processes. In the words of one team member, they felt ‘completely out of the loop’. Feedback and discovery processes were suppressed and these effects cast a shadow over the transition from vendor-focused responsibilities to HealthCo-focused responsibilities during the 10th and 11th months of the implementation. These problems dissipated as new organisational routines were introduced and regular, functional communication and coordination of activities were re-established.

In the early stages of implementation, the project team struggled to identify and supply sample ‘messages’ from a range of HealthCo and external source systems for vendor testing against the SCS messaging gateway. The message data standards on which this task relied were behind schedule. Without a useable baseline of the standards work could not proceed. The delay in attempting to create the sample messages further obscured the actual complexity and therefore the time and effort required to prepare them. This resulted in a discovery problem of a delay in HealthCo’s ability to assess the task complexity and hence the knowledge needed. This was compounded by knowledge maintenance problems due to extensive changes in governance, management and project team members through the restructuring period. In the space of a few months more than half the team comprised different people and it was operating in a different organisational context. The standards development obstacle began to dissipate in the 9th month of implementation, when the project sponsor made a decision to remove the contractor responsible from the project and provide additional HealthCo resources. Two HealthCo staff took over standards development responsibilities and this quickly alleviated feedback delays and accelerated the development and use of new knowledge in this part of the implementation.

The project schedule was revised to test with hypothetical messages that could be quickly generated ‘to spec’ rather than continue to wait for sample outputs from the actual source systems, to avoid delays with other implementation tasks. When a sufficient subset of the actual messages were obtained and tested, there were numerous structure and data quality problems. Eventually the problem was recognised to be much larger than anticipated. Realisation that the complexity of testing the real source systems against the SCS in the remaining time was far in excess of estimates came to a head in the 11th month of implementation. This highlighted the existence and subsequent correction of a knowledge acquisition problem caused by deficiencies in the conceptual maps used by organisational members to guide analysis and generate solutions. Much later, a team member reflected on this problem at a project review. He emphasised a testing automation tool developed by the vendor team members as a critical breakthrough in helping him conceptualise and systematically manage the many variables in the integration process. This artefact was a tangible example of tacit knowledge that had been codified shared and applied to overcome the knowledge barrier.

As the complexity of integration and testing knowledge required became clearer, a major project review was convened in the 11th month. The team learned that it would take several months more work to complete and that more people with specialist knowledge were going to be needed. The main outcomes of the review were actions to reduce the complexity of the initial launch by focusing on just one of the two pilot sites, to increase the time remaining from 2 to 5 months, and to increase resources for the project to fill a number of roles where it was now recognised that particular expertise was needed. The areas of expertise identified were project monitoring and reporting, implementation coordination, and integration testing.

The additional project monitoring and reporting was providing additional feedback to the project team on progress to goals, and over the remaining months further simplification of the launch plan was needed to phase the introduction of source system data feeds. In an interview with the program manager after launch was achieved, he reflected that even if time had allowed a more complete launch in terms of source systems and pilot sites, knowing in hindsight how many interdependencies existed he would still elect to have approached it in the incremental way that eventually prevailed through necessity. Actions of technology scope reduction and implementation process simplification were employed as for overcoming the knowledge barriers encountered.

Learning outcomes

Two major learning outcomes emerge from this limited case scenario. Firstly, tacit knowledge of gained from adapting the standards to the technology components of the innovation was most effectively converted to an explicit representation for sharing among the team after the organisation replaced an external consultant with more labour-intensive ‘learning-by-doing’ of dedicated internal personnel. Thus, reducing delays in the conversion of tacit standards knowledge into explicit and communicable form was one important action to overcome this knowledge barrier. Secondly, detailed technical knowledge of how to test and verify that a source system was successfully integrated with the SCS was far more applicable following a team member’s effort to develop a tool that packaged it into a ‘black-box’ for others to use without having to re-learn. Thus, another action to overcome the knowledge barrier was to effectively reduce the complexity of knowledge needed to perform testing tasks. As a backdrop to all this, actions to re-establish routines of coordination between restructured entities at HealthCo were important in reducing organisational uncertainty and correcting problems in the learning process.

CONCLUSIONS

Knowledge barriers were defined in this paper as obstacles to action requiring technical knowledge in innovation, experienced by actors as a need for excessive resources in organisational learning. Through a synthesis of prior research on antecedents to technical knowledge and organisational learning problems, a framework was developed that provides multiple explanations for the sources of knowledge barriers. A case study of complex technology innovation in the Australian health sector was used to demonstrate and support the framework. The value of this research is to offer a more complete understanding of knowledge barriers and how they arise. This is the first step towards understanding action that can effectively overcome knowledge barriers. Future research is needed to rigorously test the framework, link causes with actions that organisations can take to reduce the labour of learning, and hence reduce the incidence and impact of knowledge barriers.

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