December 2006

Design Theory: Supporting the Discovery of Novel Knowledge in Organizations

Tracy Jenkin
Queen's University

Design Theory: Supporting the Discovery of Novel Knowledge in Organizations

Tracy A. Jenkin
Queen's University
tjenkin@business.queensu.ca

ABSTRACT

In my dissertation, I examine novel knowledge discovery in the context of organizational learning. Novel knowledge, defined as knowledge that is potentially strategically important to the organization, not currently known to the organization, indirectly relevant and therefore difficult to find, is proposed to be one of three different types of knowledge that organizations seek to discover in their environment. A taxonomy is developed to differentiate three levels of knowledge discovery in the environment, including goals and tools to support these goals. However, tools supporting the discovery of highly novel knowledge are rare compared to tools supporting the other levels of knowledge discovery. Accordingly, a design theory for novel-knowledge-discovery tools is proposed based on organizational learning theories. The results are proposed to demonstrate how novel-knowledge-discovery tools can support organizational learning.

Keywords

Knowledge discovery, design theory, organizational learning, novel knowledge

INTRODUCTION

Scanning the environment and developing interpretations in order to 'know' the environment is an important organizational activity (Daft and Weick, 1984). Organizations seek different types of knowledge in their environment; novel knowledge is proposed to be one of these types. Novel knowledge, defined as knowledge that is not currently known to the organization, interesting, indirectly related and thus difficult to find, can be of significant strategic importance to the organization (Vats and Skillicorn, 2004). Unfortunately, organizations face several challenges discovering novel knowledge in their environment, for example: 1) difficulty locating novel knowledge in the vast amounts of information available online, (Chung, Chen and Nunamaker Jr, 2005), and 2) difficulty recognizing novel knowledge, once located, as relevant and significant (Schulz, 2001; Vats and Skillicorn, 2004). A novel finding may be strategically important to the organization, but if outside an organization's mental models, norms and underlying assumptions, novel findings may be interpreted as irrelevant.

There are a number of different tools and technologies that can help organizations find and make sense of information on the Web and direct the organization's attention to consequential information (Chung et al., 2005; Rao, 2004). The process of external knowledge discovery varies across organizations; the process is *firm-specific* and *goal-specific*. Thus, it is unlikely that any one tool will address all knowledge discovery needs. Knowledge represents information with direction, which enables action and decisions (Beccerra-Fernandez, Gonzalez and Sabherwal, 2004). Knowledge discovery is defined as the development of new[1] knowledge based on the analysis of data and information, or the integration and reinterpretation of prior knowledge (Beccerra-Fernandez et al., 2004). External knowledge discovery refers to the discovery of knowledge external to, and outside the organization. In my dissertation, I develop an externally-oriented knowledge-discovery taxonomy that identifies three knowledge discovery levels, goals and tools. Specifically, I address an area of knowledge discovery that has not received much attention to date: the discovery of novel knowledge. Tools to support the discovery of highly novel knowledge are rare compared to tools supporting other levels of knowledge discovery. Accordingly, a design theory for novel-knowledge-discovery tools is proposed based on organizational learning theories. Thus, the research question addressed in this research is: can a tool be designed to discover novel knowledge, and if so, what design properties should the tool have in order to be effective?

[1] New to the recipient.

This paper is organized as follows. I begin with a brief review of the knowledge discovery and organizational learning literatures. Next, I describe the theoretical models proposed to address the research question noted above. Finally, I discuss the proposed research design and anticipated contributions.

LITERATURE REVIEW

In order to understand and examine external knowledge discovery and more specifically novel knowledge discovery, the literatures on knowledge discovery and organizational learning were reviewed.

Knowledge Discovery

Previous research on knowledge discovery, spanning literatures such as data and text mining (e.g. Chung et al., 2005), decision support and expert systems (e.g. Vandenbosch and Huff, 1997), and innovation (e.g. Majchrzak, Cooper and Neece, 2004), has focused on several aspects of knowledge discovery and categorized knowledge discovery in a number of ways. Knowledge discovery has been discussed in terms of behaviours, goals, tools and techniques. Within each of these aspects of knowledge discovery, different types of knowledge discovery have been discussed (see Table 1).

Aspect of Knowledge Discovery	Type of Knowledge Discovery	Reference
Behaviour	Browsing	(Chung et al., 2005)
	Information retrieval	(Rao, 2004)
	Developing an understanding	(Rao, 2004)
	Information interpretation	(Daft and Weick, 1984; Huber, 1991)
	Scanning	(Daft and Weick, 1984; Huber, 1991; Vandenbosch and Huff, 1997)
	Focused search	(Huber, 1991; Vandenbosch and Huff, 1997)
Goals	Exploration	(Crossan, Lane and White, 1999; Schulz, 2001)
	Exploitation	(Crossan et al., 1999; Schulz, 2001)
	Knowledge reuse	(Majchrzak et al., 2004; Markus, 2001)
	Competitive intelligence	(Chen, Chau and Zeng, 2002; Day, 2002)
Tools/Technique	Web mining approaches	(Chen et al., 2002; Chung et al., 2005)
	Display/usability	(Chung et al., 2005; Shneiderman, 1996)
	Nature of user-system interaction	(Chen et al., 2002; Rao, 2004)
	Handoff between user-system	(Rao, 2004)

Table 1 - Review of Previous Knowledge Discovery Research

Although the behavioural, goal and technology-oriented aspects have been discussed in the literature, a classification based on type of knowledge to be discovered and the appropriate tool type is lacking. The only studies that appear to discuss the type of knowledge discovered are those differentiating between exploration and exploitation (Crossan et al., 1999; Schulz, 2001), and new and existing knowledge (Majchrzak et al., 2004). However, these knowledge types do not cover the breadth of knowledge and goals sought by organizations when they engage in knowledge discovery processes, nor do they discuss the appropriate tools that align with such knowledge types[2]. The external knowledge-discovery taxonomy developed in this research addresses these gaps.

[2] However, the relationship between knowledge goals sought for knowledge reuse and appropriate tools is discussed (Markus 2001).

Organizational Learning

Organizational learning theories provide insight into how organizations can overcome the challenge of 'sticky' mental models – knowledge structures that represent knowledge as a complex network of concepts with abstract attributes, values, relationships and rules (Barsalou, 1992). Individuals have their own unique mental models; whereas the organization's mental models are shared, negotiated understandings (Kim, 1993). Although mental models are useful for making sense of information, they affect what the individual and organization search for and see in the environment (Kim, 1993), thus acting as blinders to novel knowledge and opportunities (Day, 2002). Double-loop learning, which involves surfacing, challenging and changing norms, assumptions, and mental models that were previously inaccessible (Argyris and Schon, 1978; Fiol and Lyles, 1985; Kim, 1993), may allow organizations constrained by their mental models, to change and discover novel knowledge.

Organizational learning is related to and distinct from individual learning. Both relate to an increase in the capacity to take effective action (Kim, 1993). Although individual learning contributes to organizational learning, what an organization learns is not the sum of what individuals in the organization learn (Crossan et al., 1999; Fiol and Lyles, 1985; Kim, 1993). Individual and organizational learning are connected through the organizational learning process.

The organizational learning process has been conceptualized as a multi-level dynamic process, including feed-forward and feedback processes (Crossan et al., 1999) (see Figure 1). These processes span the individual, group and organizational levels, and include the following: intuiting, interpreting, integrating and institutionalizing. Another organizational learning model includes scanning – monitoring and collecting data from the environment – as part of the organizational learning process (Daft and Weick, 1984).

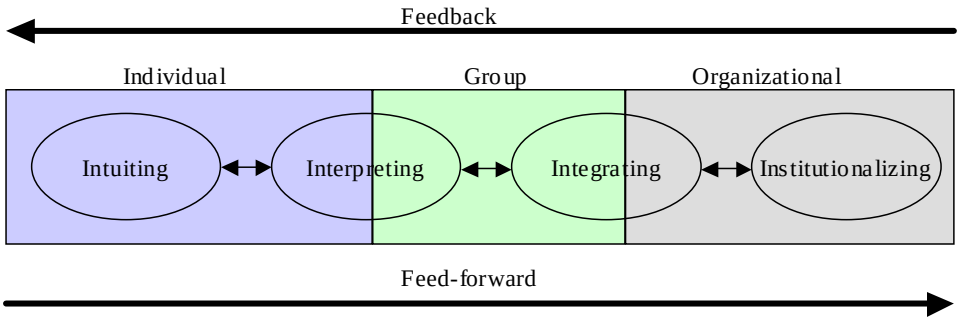

Figure 1 - Organizational Learning Process (adapted from Crossan et al., 1999)

The feed-forward process of organizational learning, the focus here, is an exploratory process that translates individual and group insights into learning that is institutionalized (Crossan et al., 1999). The connection between individual and organizational learning is the transfer and absorption of individual mental models into the organization's shared mental models (Kim, 1993). The group processes of interpreting and integrating, where a shared, negotiated understanding is developed, mediate this process.

Learning Novel Concepts

The literature reveals two competing views regarding the most effective way to learn new concepts. One view suggests that to learn something with a high degree of novelty and modify mental models, current mental models must either be separated from the learning process, for example 'opportunistic learning' (Kim, 1993), or discarded altogether, for example removing top managers (Nystrom and Starbuck, 1984). In contrast, the second view argues that learning new concepts must be grounded in familiar knowledge and mental models (Hargadon and Douglas, 2001).

To address these competing theories, an alternative view is proposed. Learning novel concepts may be enabled through reframing – conceptualizing existing mental models and knowledge in a new frame. For example, reframing a problem can result in solutions that provide a discontinuous improvement (Kim, 1993).

THEORETICAL DEVELOPMENT

External Knowledge-Discovery Taxonomy

The proposed knowledge-discovery taxonomy specifies levels of knowledge discovery, goals supported, and technologies and tools to support these goals (see Figure 2). An organization may utilize a subset or all levels to varying degrees.

Level of novelty ↓

Levels of Knowledge Discovery	Focus	Goals	Technologies & Tools
Discovering incremental details about what is already known	Similarity	Support and confirm knowledge. Augment knowledge. Deepen understanding.	Search engines, Semantic web technologies
Discovering the multiple dimensions of a concept and relationships with other concepts	Conceptual dimensions/ categories, relationships	Develop categories. Develop conceptual maps. Broaden understanding.	Categorization tools, Ontology development tools, Semantic web technologies
Discovering novel knowledge	Novelty	Find unknown, relevant, indirectly connected information.	Unknown

Figure 2 – Externally-Oriented Knowledge-Discovery Taxonomy

The novelty of knowledge discovered increases across the three levels. All knowledge discovered is new to the recipient; the important distinction is the degree of 'newness' and surprise to the recipient. One of the distinguishing features of novel-knowledge-discovery (NKD) tools, as differentiated from the other levels, is that the tool directs the organization's attention to what they should do or learn next (Vats and Skillicorn, 2004). This feature will help reduce the information overload problem experienced in the other levels. Thus, I propose:

P1: Three knowledge-discovery levels can be differentiated by the degree of novelty of the knowledge sought.

P2: Three associated levels of knowledge-discovery tools exist, differentiated by the degree of novelty of the knowledge provided.

More specifically, I propose:

P2a: Level one knowledge-discovery tools, such as Google, discover incremental details about what is already known to deepen one's understanding of a concept.

P2b: Level two knowledge-discovery tools, such as Vivisimo[3], discover multiple dimensions of a concept and relationships with other concepts to broaden one's understanding of a concept.

P2c: Level three knowledge-discovery tools, such as Athens[4], perform the functions stipulated by the Novel-Knowledge-Discovery design principles (see below).

[3] Vivisimo (www.vivisimo.com) displays results in clusters.

[4] Athens 2.0 developed in this research, an extension of Athens 1.0 (Vats and Skillicorn, 2004), is an instantiation of the NKD design theory.

Novel-Knowledge-Discovery Design Theory

Design theory is an approach to research where artifacts designed to address an existing yet unsolved problem are built and evaluated (Hevner, March, Park and Ram, 2004). Design theory is a prescriptive theory specifically focused on goal achievement in addition to explanation and prediction (Walls, Widmeyer and El Sawy, 1992). A design theory consists of 1) kernel theories, from social and natural science theories, which illuminate the problem and drive design properties, 2) meta-requirements, the class of goals and problems to be addressed by the theory, 3) meta-design, a class of artifacts or set of design principles to address the meta-requirements, and 4) testable hypotheses used to test the resulting theory (Walls et al., 1992). Design theory provides a link between problem-space and solution-space. The theory created helps predict whether a design will solve the class of problems it was designed to address (Venable, 2006).

The meta-requirements, or class of problem, being addressed in this study are the challenges associated with the discovery of novel knowledge, despite its potential significance to the organization. The kernel theories that explain these challenges, as well as highlight potential design properties, are the knowledge discovery and learning theories discussed above. The proposed design principles[5] that address the challenges of discovering novel knowledge are derived from these kernel theories. The proposition associated with this design theory is:

> **P3:** A tool that adheres to the NKD design principles will be more effective in enabling the discovery of novel knowledge than tools designed to discover knowledge at levels one and two.

NKD tools are proposed to support individual-level learning processes. However, NKD tools do not directly support group and organizational processes. Integrating processes at the group-level, such as consensus-building and decision-making, are supported more effectively by GDSS tools (Desanctis and Gallupe, 1987; Sambamurthy and Poole, 1992). The degree to which the group's decision and actions regarding novel knowledge are integrated and later institutionalized within the organization depends on whether organizational members understand and agree upon the new shared understanding.

PROPOSED RESEARCH DESIGN

The research design will proceed in two phases. In phase one, a case study of an organization using an early version of Athens (Vats and Skillicorn, 2004), a tool that partially addresses the NKD design theory, will be conducted. The results of this case study will help inform the design theory and experimental design, and may result in modifications to both.

The goal of phase one is to explore how an organization uses an NKD tool in practice. The newness of this technology implies that little is known about how organizations use tools to discover novel knowledge. Since only one organization has adopted Athens, a single, revelatory case will be studied (Yin, 1994). Multiple sources of data will be utilized: interviews, observation, and search results from Athens.

In phase two, Athens will be modified to fully align with the NKD design theory. An experiment to test the NKD design theory and propositions that differentiate knowledge discovery levels and tools will also be conducted. Since the second goal of phase two is to test predictions, the experiment was deemed an appropriate research design. To maximize realism, organizational participants will be recruited from within a firm, selected according to predefined criteria such as industry, size and reputation for innovation. The task will involve groups using technology – knowledge-discovery and GDSS tools – to address an emerging market issue. The effectiveness of the NKD tool in the feed-forward portion of the organizational learning process, the treatment condition, will be tested against the effectiveness of tools at levels one and two, the control conditions (see Table 2).

PROPOSED CONTRIBUTION

This study is intended to help organizations understand the dimensions of knowledge discovery, and the tools that can assist them in knowing their environment. In addition, understanding the utility of the NKD design theory and how it supports the organizational learning process can guide future researchers and practitioners in the development and use of NKD tools.

By integrating social science theory with design theory, this research addresses the call for additional design theory research in MIS (e.g. Hevner et al., 2004). Lastly, this study addresses calls for more research to explore how information systems can support organizations in the examination and modification of assumptions, norms and mental models (e.g. Orlikowski and Gash, 1991), and to explore the uncertain relevance of novel knowledge (e.g. Schulz, 2001).

---

[5] Space constraints prevent a full discussion of the proposed design principles here.

	Treatment Condition	**Tool**	**Propositions Tested**
1	Level one knowledge-discovery tool used with GDSS tool.	Google	P1, P2a
2	Level two knowledge-discovery tool used with GDSS tool.	Vivisimo	P1, P2b
3	Level three knowledge-discovery tool used with GDSS tool.	Athens	P1, P2c, P3
Task:			
1. After training, each group will be given an emerging market issue.			
2. Each individual within the group will use the assigned tool to discover knowledge.			
3. Results from each individual's search will be combined into one list by the facilitator. Ideas will be anonymous.			
4. The facilitator, using the GDSS tool, will facilitate a group discussion to discuss the relevancy and importance of each idea. Ideas will be rated for relevancy and novelty. Group will choose one idea to pursue to address the emerging market issue.			
5. Three senior executives will evaluate the chosen ideas.			

Table 2 – Summary of Treatment Conditions and Experimental Task

ACKNOWLEDGMENTS

I thank Yolande Chan, David Skillicorn, Jim McKeen and M. Lynne Markus for their helpful suggestions and support.

REFERENCES

1. Argyris, C. and Schon, D.A. (1978) Organizational learning, Addison-Wesley, Reading, MA.
2. Barsalou, L.W. (1992) Frames, concepts, and conceptual fields, in E. Kittay and A. Lehrer (eds.) *Frames, fields, and contrasts: New essays in semantic and lexical organization*, Erlbaum, Hillsdale, NJ, 21-74.
3. Beccerra-Fernandez, I., Gonzalez, A., and Sabherwal, R. (2004) Knowledge management: Challenges, solutions, and technologies, Pearson Prentice Hall, Upper Saddle River, NJ.
4. Chen, H., Chau, M., and Zeng, D. (2002) CI Spider: A tool for competitive intelligence on the Web, *Decision Support Systems*, 34, 2002, 1-17.
5. Chung, W., Chen, H., and Nunamaker Jr, J.F. (2005) A visual framework for knowledge discovery on the web: An empirical study of business intelligence exploration, *Journal of Management Information Systems*, 21, 4, 57-84.
6. Crossan, M.M., Lane, H.W., and White, R.E. (1999) An organizational learning framework: From intuition to institution, *Academy of Management Review*, 24, 2, 522-537.
7. Daft, R.L. and Weick, K.E. (1984) Toward a model of organizations as interpretation systems, *Academy of Management Review*, 9, 2, 284-295.
8. Day, G.S. (2002) Managing the market learning process, *The Journal of Business & Industrial Marketing*, 17, 4, 240-252.
9. Desanctis, G. and Gallupe, R.B. (1987) A foundation for the study of group decision support systems, *Management Science*, 33, 5, 589-609.
10. Fiol, C.M. and Lyles, M.A. (1985) Organizational learning, *Academy of Management Review*, 10, 4, 803-813.
11. Hargadon, A.B. and Douglas, Y. (2001) When innovations meet institutions: Edison and the design of the electric light, *Administrative Science Quarterly*, 46, 476-501.
12. Hevner, A.R., March, S.T., Park, J., and Ram, S. (2004) Design science in Information Systems research, *MIS Quarterly*, 28, 1, 75-105.

13. Huber, G.P. (1991) Organizational learning: The contributing processes and the literatures, *Organization Science*, 2, 1, Special Issue: Organizational Learning: Papers in Honor of (and by) James G. March, 88-115.
14. Kim, D.H. (1993) The link between individual and organizational learning, *Sloan Management Review*, 35, 1, 37-50.
15. Majchrzak, A., Cooper, L.P., and Neece, O.E. (2004) Knowledge reuse for innovation, *Management Science*, 50, 2, 174-188.
16. Markus, M.L. (2001) Toward a theory of knowledge reuse: Types of knowledge reuse situations and factors in reuse success, *Journal of Management Information Systems*, 18, 1, 57-93.
17. Nystrom, P.C. and Starbuck, W.H. (1984) To avoid organizational crises, unlearn, *Organizational Dynamics*, 12, 4, 53-65.
18. Orlikowski, W.J. and Gash, D.C. (1991) Changing frames: Understanding technological change in organizations, in *Academy of Management Best Paper Proceedings*, 51st Annual Meeting, Miami Beach, FL, August.
19. Rao, R. (2004) Leveraging content in enterprise knowledge processes, in M. Rao (ed.) *Knowledge scaffolding: How practitioners use knowledge management tools*, Butterworth-Heienemann.
20. Sambamurthy, V. and Poole, M.S. (1992) The effects of variations in capabilities of GDSS designs on management of cognitive conflict in groups, *Information Systems Research*, 3, 3, 224-251.
21. Schulz, M. (2001) The uncertain relevance of newness: Organizational learning and knowledge flows, *Academy of Management Journal*, 44, 4, 661-681.
22. Shneiderman, B. (1996) The eyes have it: A task by data type taxonomy for information visualizations, in *IEEE Symposium on Visual Languages*, Los Alamitos, CA, IEEE Computer Society Press, 339-343.
23. Vandenbosch, B. and Huff, S.L. (1997) Searching and scanning: How executives obtain information from executive information systems, *MIS Quarterly*, 21, 1, 81-107.
24. Vats, N. and Skillicorn, D.B. (2004) The ATHENS system for novel information discovery, Queen's University School of Computing, Technical Report 2004-489.
25. Venable, J. (2006) The role of theory and theorizing in design science research, in *First International Conference on Design Science Research in Information Systems and Technology*, February 24-25, Claremont, CA.
26. Walls, J.G., Widmeyer, G.R., and El Sawy, O.A. (1992) Building an information system design theory for vigilant EIS, *Information Systems Research*, 3, 1, 36-59.
27. Yin, R.K. (1994) Case study research: Design and methods, Sage Publications, Thousand Oaks, CA.