Toward Integrating Knowledge Management, Processes and Systems: A Position Paper

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Abstract

Taking a first step toward an integrated approach to knowledge process and system design, we draw from the literature to develop an amalgamated knowledge management life cycle model. We use this model to classify and analyze a number of extant knowledge management systems and practices. The resulting classification elucidates several informative similarities and differences between the diverse sets of systems and practices. And the analysis interrelates the various classes with discrete phases of an amalgamated knowledge management life cycle model. This represents a central contribution of the paper, as it reveals the underlying components of knowledge management and links them to methods currently available for knowledge system and process development.

Knowledge Management and System Design

The power of knowledge has long been ascribed to successful individuals in the organization, but today it is recognized and pursued at the enterprise level through a practice known as knowledge management (see Davenport and Prusak 1998). Although knowledge management has been investigated in the context of decision support systems (DSS) and expert systems (ES) for over a decade (e.g., see Shen 1987), interest in and attention to this topic have exploded recently. For example, knowledge capital is commonly discussed as a factor of no less importance than the traditional economic inputs of labor and finance (Forbes 1997), and the concept *knowledge equity* is now receiving theoretical treatment through research (e.g., see Glazer 1998).

Many prominent technology firms now depend upon knowledge-work processes to compete through innovation more than production and service (McCartney 1998), and Drucker (1995, p. 271) writes, "knowledge has become the key economic resource and the dominant—and perhaps even the only—source of comparative advantage." This follows his assertion that increasing knowledge-work productivity represents the great management task of this century, on par with the innovation and productivity improvements made through industrialization of manual-work processes (Drucker 1978). Brown and Duguid (1998, p. 90) add, "organizational knowledge provides synergistic advantage not replicable in the marketplace." Indeed, some forecasts suggest knowledge work (e.g., performed by professionals and managers) will account for nearly 25% of the workforce soon after the 21st century begins (Labor 1991). And partly in anticipation, fully 40% of Fortune-1000 companies claim to have established the role of Chief Knowledge Officer (CKO) in their companies (Roberts 1996). Miles et al. (1998, p. 281) caution, however, "knowledge, despite its increasing abundance, may elude managerial approaches created in 20th century mindsets and methods."

But knowledge is proving difficult to manage, and knowledge work has been stubbornly resistant to reengineering and process innovation (Davenport 1995). Moreover, most information technology (IT) employed to enable knowledge work appears to target data and information, as opposed to knowledge itself (cf. Ruggles 1997). We feel this contributes to difficulties experienced with knowledge management to date. Knowledge, almost by definition, lies at the center of knowledge work, yet it is noted as being quite distinct from data and information (e.g., see Davenport et al. 1998, Nonaka 1994, Teece 1998). Drawing from Arrow (1962) and others, we understand that even information economics has many important differences from standard economic theory (e.g., negligible marginal costs, network externalities, consumption without loss of use), but our understanding of *knowledge economics* is entirely "primitive" (Teece 1998).

Further, extant IT used to support knowledge management is limited primarily to conventional database management systems (DBMS), data warehouses and mining tools (DW/DM), intranets/extranets and groupware (O'Leary 1998). Arguably, just looking at the word "data" in the names of many "knowledge management tools" (e.g., DBMS, DW/DM), we are not even working at the level of information, much less knowledge.

Even more troublesome is the widespread implementation of IT to support knowledge management without commensurate redesign of the underlying processes. As we learned through the painful, expensive and failure-prone "first wave" of reengineering (see Cypress 1994), simply inserting IT into a process in no way guarantees performance improvement. This point is underscored by Hammer (1990), who colorfully refers to such practice as "paving the cowpaths" (e.g., making a broken process simply operate broken faster).

Drawing all the way back to Leavitt (1965) and others (e.g., Davenport 1993, Nissen 1998), new IT needs to be integrated with the design of the *process* it supports, which includes consideration of the organization, people, procedures, culture and other key factors, in addition to technology. Such integration of knowledge process design with knowledge system design is strangely missing from the knowledge management literature and practice.

The research described in this paper is focused on knowledge management and system design from three integrated perspectives: 1) reengineering process innovation, 2) expert systems knowledge acquisition and representation, and 3) information systems analysis and design. Our position is, we can integrate these three perspectives in a systematic manner, beginning with analysis and design of the enterprise process of interest, progressively moving into knowledge capture and formalization, and then system design and implementation. Thus, we strive to offer an integrated approach that covers the gamut of design considerations from the enterprise process in the large, through alternative classes of knowledge in the middle, and on to specific systems in the detail.

The central premise of this position is, although knowledge management represents a phenomenon of relatively new widespread interest and attention in research and practice, many of its underlying elements are actually quite familiar and have been effectively addressed for many years (decades in some cases). This includes work in process redesign (e.g., integration of information technology enablers with organizational design, human resources, information availability, inter-organizational alliance, workflow modification and other process transformations), artificial intelligence (e.g., knowledge capture and formalization, distributed inference, knowledgebase design) and information systems (e.g., structured and object-oriented analysis & design, database development, decision support systems). At this stage of our research, we have identified many compelling examples of well-established methodologies, techniques and tools being composed to support integrated analysis and design of knowledge systems and processes.

Much of the research outlined in the position statement above is underway. In the balance of this paper, we draw from the literature to develop an amalgamated knowledge management life cycle model. We use this to classify and analyze a number of extant knowledge management systems and practices. The resulting classification elucidates several informative similarities and differences between the diverse sets of systems and practices. And the analysis interrelates the various classes with discrete phases of our amalgamated knowledge management life cycle model. This represents a central contribution of the paper, as it reveals the underlying components of knowledge management and links them to methods currently available for knowledge system and process development.

Table 1 Knowledge Management Life Cycle Models

Model	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Nissen	Capture	Organize	Formalize	Distribute	Apply
Despres and Chauvel	Create	Map/bundle	Store	Share/transfer	Reuse
Gartner Group	Create	Organize	Capture	Access	Use
Davenport & Prusak	Generate		Codify	Transfer	
Amalgamated	Create	Organize	Formalize	Distribute	Apply

Amalgamated Knowledge Management Life Cycle Model

Drawing from Nissen (1999), we begin to observe a sense of process flow or a life cycle associated with knowledge management. Although we can describe the knowledge management life cycle as a sequence of activities, in practice their performance is generally iterative. Building upon this notion, we outline key elements of several life cycle models drawn from the recent knowledge management literature to develop an amalgamated knowledge management process model. In Table 1, we compare the knowledge management life cycles proposed by several researchers (e.g., Nissen 1999, Despres and Chauvel 1999, Gartner Group 1999, Davenport and Prusak 1998), which all share considerable similarities.

Table 2 Organization Level Systems and Practices

Create	Organize	Formalize	Distribute	Apply	Evolve
Data mining	Knowledge map	Data warehouse	FAQs	BPR	
AI first principles	Semantic network	Reports	Best practices		
R&D	GrapeVines		Lessons learned		
Bench marking			Knowledge brokers		
Business intel			"Yellow Pages"		
			Web publication		
			Document search		

For instance, most of the four life cycle models begin with a "create" or "generate" phase; only the Nissen model begins with knowledge capture, an activity appearing in the *third* phase of the Gartner Group model. The second phase pertains to the organization, mapping or bundling of knowledge; Davenport and Prusak omit this organization phase from their model, but it appears very prominently in all the others. Phase three uses different terms across the models, but they all address some mechanism for making knowledge formal or explicit. Likewise, the fourth phase uses different terms but addresses the ability to share or distribute knowledge in the enterprise. Three of the four models include a fifth phase for application or (re)use of knowledge for problem solving or decision making in the organization. Only the Despres and Chauvel model includes a sixth phase for knowledge evolution.

The Amalgamated model integrates the key concepts and terms from the four life cycle models. Comparing the steps above proposed by Nissen (1999) with this Amalgamated model, notice from Table 1 the latter life cycle model makes a distinction between knowledge creation (e.g., as proposed by Despres and Chauvel and Gartner Group) and its capture or formalization (i.e., Phase 3). Whereas knowledge creation involves discovery and the development of new knowledge, knowledge capture requires only that the knowledge be new to a particular individual or organization, and formalization involves the conversion of existing knowledge from tacit to explicit form. The Amalgamated model therefore seems more complete with its beginning at the creation step. Similarly, the Amalgamated model also adopts the evolution step from the Despres and Chauvel model. We continue with this model through the sections that follow.

Knowledge Management Systems and Practices

In this section, we draw again from Nissen (1999) to examine a number of extant systems and practices employed in the context of knowledge management. To facilitate analysis, we map these systems and practices to discrete phases of the Amalgamated Knowledge Management Life Cycle Model developed above. These amalgamated life cycle phases are repeated across the tops of Tables 2-5 for reference. The cells of Tables 2-4 contain examples of current knowledge management systems and practices drawn from the literature (e.g., Davenport et al. 1996, Davenport and Prusak 1998, Gartner Group 1999, Despres and Chauvel 1999, others). We use these exemplars from current practice, not only to populate the table cells, but also to interrelate them with points along the life-cycle dimension.

However, in addition to this life-cycle dimension, we find higher dimensionality is required to map the more dynamic knowledge management activities summarized in Table 1. One important dimension along these lines is *knowledge management level*, which draws from Nonaka (1994) and others (e.g., Despres and Chauvel 1999). The knowledge management level includes both individual and collective entities, the latter of which are further distinguished between groups (e.g., of relatively small collections such as work teams or functional departments) and organizations (e.g., relatively large collections such as enterprises or corporations). This dimension pertains to the scale of knowledge management and extends from a single person, through work groups, to an enterprise as a whole. Combined with the life cycle steps from above, we employ these levels in a two-dimensional framework to classify extant knowledge management applications.

Table 3 Group Level Systems and Practices

Create	Organize	Formalize	Distribute	Apply	Evolve
	Engr BoK		Workflow	Group DSS	
	Knowledge Exchange		Groupware		
			Community of practice		
			Discussion groups		
			Document sharing		
			Workshops		
			Listservers		
			Tele conference		
			E-mail		
			Meetings		

We begin the discussion with Table 2, which pertains to organization-level knowledge management. Tables 3 and 4 are presented subsequently to incorporate systems and practices applied at the group and individual levels, respectively. In discussing these tables, a number of points merit noting. First, arguably, knowledge creation represents a more difficult and uncertain process than its capture. Indeed, referring to Tables 2-4, few systems exist to support knowledge creation—data mining system conglomerates and artificial intelligence (AI) from first principles represent notable exceptions—but a number of enterprise practices (e.g., corporate research and development (R&D), benchmarking, competitive business intelligence) are widely employed for this purpose.

Second, referring back to Table 1, the Gartner Group collects the organize, formalize and distribute activities under the common heading "knowledge sharing." We use this grouping below to help classify and cluster extant knowledge management technologies and practices. Continuing across the rows of Table 2, examples of systems used for enterprise-wide knowledge organization include knowledge maps and semantic networks. And from Table 3, group-level implementations such as Chrylser's Engineering Book of Knowledge and Anderson Consulting's Knowledge Exchange are also noted in the literature. Table 4 reveals that, at the individual level, systems to extract and cluster information by keyword are available, along with the online thesaurus to interrelate key terms and concepts in the enterprise. And knowledge-based systems (KBS; e.g., expert systems, intelligent agents) address knowledge directly and employ a variety of knowledge representational techniques for its organization. Without going into great detail, notice a number of systems and practices listed under the knowledge formalization and distribution columns. Clearly, this represents the current emphasis of most knowledge management today.

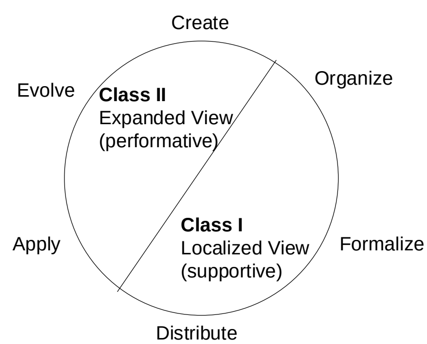

Figure 1 Knowledge Management Life Cycle

Third, we note above the Despres and Chauvel life cycle includes a sixth element, called "evolution," to represent the refinement and continued development of existing knowledge. With a little thought, one can see such refinement and continued development is similar in many respects to the "maintenance" phases of the developmental life cycle models common to system and process development. These models include, for example, the information system development life cycle model (SDLC), several expert system development models and various approaches to business process reengineering (BPR). And as with nearly all life cycle models—which we note are laid-out sequentially but generally performed in an iterative manner—we can also say that knowledge evolution leads in turn to further knowledge creation, thereby completing the cycle and signaling the beginning of new knowledge capture and sharing (e.g., additional organization, formalization and distribution of knowledge).

The cyclical nature is more readily discernable when presented as a circle, as opposed to a linear sequence of activities, as depicted in Figure 1. Notice the three "sharing" activities from above—knowledge organization, formalization and distribution—are adjacent on the right-hand side of the cycle. From the tables above, we see these activities correspond with greater support from extant information technologies and hence represent more of a localized view of knowledge management; thus, the grouping under the "Class I" heading in the figure. We note such, localized knowledge management systems are inherently supportive in nature; that is, this class of implementations to organize, formalize and distribute knowledge in the enterprise *support* people in the loop, who in turn apply, evolve and create knowledge in the organization.

Alternatively, the latter three, non-sharing activities are adjacent on the left-hand side of the cycle. But from the tables we see these activities do not correspond well with support from extant information technologies and hence represent an expanded view of knowledge management; thus, the grouping under the "Class II" heading in the figure. We note such, expanded knowledge management systems are inherently performative in nature; that is, this class of implementations to apply, evolve and create knowledge in the enterprise *perform* knowledge-management activities, either in conjunction with or in lieu of people in the organization. Referring back to the tables above, however, we note very few extant knowledge management systems currently capable of performing in this manner. This may highlight a promising area for future knowledge management research and system development.

Table 4 Individual Level Systems and Practices

Create	Organize	Formalize	Distribute	Apply	Evolve
	Keyword extract		Information retrieval	Data visualization	
	Online thesaurus		Document mgmt		
	KBS	KBS	KBS	KBS	

Principal Information Technologies

Table 5 extends the classification of extant knowledge management systems and practices by identifying the principal information technologies (ITs) and redesign transformations used to enable systems and practices from the various classes and life cycle phases. Take the first technology listed under the "create" column, for instance. This entry corresponds with the data mining class of systems identified in Table 2 above. Here, Table 5 indicates most data mining applications are enabled by tools and techniques associated with sophisticated pattern matching. Similarly, AI first-principles reasoning is also listed under the "create" column in Table 2. Here, Table 5 indicates most first-principles applications are enabled through the kind of automated inference performed by KBS.

As other instances from Tables 2 and 5, respectively, many corporate R&D processes are transformed through concurrent engineering methods, benchmarking is generally conducted through comparative process analysis, and the collection of most competitive business intelligence is predicated on business research. The other technologies and transformations follow accordingly for Tables 2-4 and should be self-explanatory to the likely reader of this paper.

Notice, looking across the rows at the rightmost column, we identify one or more of the common methodologies identified above—reengineering (BPR), expert systems (ES) or information systems (IS)—that would be appropriate to develop each principal IT or redesign transformation. For instance, conventional IS methods are generally employed to develop association lists, and ES approaches are required for implementing most semantic nets. Several important points can be drawn from this table. First, notice the relative sparsity of applications outside the three "sharing" columns (i.e., beyond knowledge organization, formalization and distribution). At least as described in the literature, the great majority of knowledge management applications pertain to sharing knowledge that already exists in the enterprise. This supports our classification above in terms of a limited view of knowledge management, as it excludes knowledge creation, application and evolution, which are necessary to complete the life cycle. Indeed, we omit the "evolve" column in this table, because a dearth of technologies and practices is presently available for knowledge management at this step of the life cycle.

to support concurrent engineering involves both information systems and process redesign methodologies and techniques. Indeed, where certain technologies and transformations are developed *together* (e.g., combining concurrent engineering with workflow technology), data from Table 5 indicate all three developmental approaches (i.e., reengineering, expert systems and information systems) are required. The table thus suggests that no single methodology—or pair of methodologies—and related set of techniques and tools is sufficient to develop all knowledge management systems and processes. This supports our premise that an integrated approach to knowledge system and process design is necessary.

Table 5 Principal Enabling ITs and Transformations

Create	Organize	Formalize	Distribute	Apply	Developmental Approach
Pattern matching					IS, ES
Automatic inference	Automatic inference	Automatic inference	Automatic inference	Automatic inference	ES
Concurrent engr					IS, BPR
Process analysis					BPR
Business research					
	Association lists				IS
	Semantic net				ES
	Database	Database	Database		IS
	Web/Notes	Web/Notes	Web/Notes		IS
	Text search	Text index			IS
			Search engine		IS
			Workflow		IS, BPR
			Groupware		IS
			VTC		IS
			Listserver		IS
			GDSS		IS
			Graphics		IS

Second, every principal IT and transformation used to enable knowledge management systems and practices (i.e., listed in the table) is addressed by at least one current methodology. In other words, our current set of BPR, ES and IS methodologies provides the necessary set of capabilities to design and develop this entire collection of technologies and transformations used to enable extant knowledge management systems and processes. This supports our premise that extant methodologies, techniques and tools can be employed to develop knowledge management systems.

Third, a number of principal ITs and transformations require *multiple* developmental approaches. For instance, sophisticated pattern-matching tools and techniques employed to develop data mining applications require a synthesis of IS and ES approaches, and transformation of an R&D process

Conclusions and Future Research

The research described in this paper has focused on knowledge management and system design from three integrated perspectives: 1) reengineering process innovation, 2) expert systems knowledge acquisition and representation, and 3) information systems analysis and design. Our position is, we can integrate these three perspectives in a systematic manner, beginning with analysis and design of the enterprise process of interest, progressively moving into knowledge capture and formalization, and then system design and implementation. Thus, we strive to offer an integrated approach that covers the gamut of design considerations from the enterprise process in the large, through alternative classes of knowledge in the middle, and on to specific systems in the detail.

Through this paper, we draw from the literature to develop an amalgamated knowledge management life cycle model. We use this to classify and analyze a number of extant knowledge management systems and practices. The resulting classification elucidates several informative similarities and differences between the diverse sets of systems and practices. And the analysis interrelates the various classes with discrete phases of an amalgamated knowledge management life cycle model. This represents a central contribution of the paper, as it reveals the underlying components of knowledge management and links them to methods currently available for knowledge system and process development.

A number of other important findings and conclusions emerge from this research. For one, despite the abundance of knowledge management life cycles that now appear in the literature, they all share considerable similarities and can be integrated into an amalgamated model to describe a broad diversity of knowledge management work in the enterprise. As another, if harnessed appropriately, the current repertoire of IT methodologies, technologies and tools has much to offer for the design and development of knowledge management systems.

At the same time, as Tables 2-4 show, we note a relative sparsity of systems and practices associated with our expanded view of knowledge management (e.g., Class II systems and practices); that is, few extant applications and processes address the corresponding, performative knowledge management life cycle phases (i.e., apply, evolve, create). We feel this highlights a promising area for future research, particularly in the AI field. For instance, AI research has addressed knowledge application directly for several decades (e.g., through work on expert systems, planning). As another instance, machine learning algorithms explicitly address knowledge evolution (e.g., through work on rule induction, unsupervised learning), and reasoning from first principles is identified above as a viable AI approach to knowledge creation.

Another important conclusion from this research is, we feel contextual factors may play a critical role in the design and implementation of knowledge systems and processes. We contend effective knowledge management is a question of tailoring technical and process solutions to fit the exigencies of the context in which activities are being performed. Thus, we recognize the need to address this by integrating critical contextual factors into the analysis. This may represent another fruitful step for continued research along the lines of this investigation.

For instance, the design space for KM systems can be further defined and constrained by a set of contextual factors that impinge on the implementation of these systems in organizations. At this stage in the research, we can identify two primary factors: 1) the organization, and 2) the nature of knowledge underlying the task. Toward the first (i.e., addressing contextual factors associated with the organization), we would divide the research into three parts: 1) the role of organizational memory, 2) structure of the organization, and 3) organizational incentives. Toward the second (i.e., addressing the nature of knowledge underlying the task), we feel the research should at least differentiate between canonical and non-canonical practices, for which process codification is relatively more or less practical, respectively.

The work described in this paper offers several other logical extensions for future research. One such extension, for instance, would delineate the *contingent* nature of knowledge management. As an example, one could endeavor to specify in greater detail the interaction between information technologies and practices with organizational activities, thereby enabling designers to identify "families" of solutions that are likely to succeed as knowledge system and process implementations. Clearly, this represents only a short, partial list of future research topics. Knowledge management remains a relatively novel focus of research, and much work needs to be accomplished to advance our knowledge and technological level in this area. We hope to have contributed to such knowledge and level by illustrating how current systems and practices—and their corresponding developmental methods—can be mapped to our amalgamated knowledge management life cycle model. And we hope to have taken a step toward integrated analysis and design of knowledge systems and processes.

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