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TOWARDS A DESIGN THEORY FOR PROCESS-BASED KNOWLEDGE MANAGEMENT SYSTEMS

Research-in-Progress

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Abstract

In today's knowledge economy, organizations need to effectively manage their knowledge to support an increasing number of knowledge intensive business processes. Such knowledge-intensive business processes could be more effectively supported by Process-based knowledge management (PKM) systems that integrate knowledge management services with process management systems. However, currently there are minimal design guidelines for developing such PKM systems. In this research-in-progress paper, we highlight this research problem, and propose a preliminary framework that can be extended to serve as a design theory for developing process-based knowledge management systems. Specifically, we identify kernel theories governing the design and development of PKM systems, and propose a design process for developing PKM systems. We also identify future research opportunities for further extending the framework and its evaluation.

Keywords: design theory, knowledge-intensive process, business process management, knowledge management

Introduction

In today's knowledge economy, a significant portion of business processes involve knowledge work and require knowledge flow support to enable efficient execution of the business processes. While traditional business process automation systems have helped significantly improved worker and organizational productivity in the past (Choenni et al. 2003; Kueng 2000; Reijers and van der Aalst 2005), organizations are now looking beyond routine business processes to provide support for processes that are highly dependent on human expertise and judgment, and are thus knowledge-intensive. Economic and business shifts in the global economy such as the shortening of product life cycles, increasing competition, and changing market dynamics are driving a major change in the nature of work requiring the seamless support of knowledge-intensive business processes through the integration of disparate tools and knowledge sources to improve knowledge worker productivity (Moore and Rugullies 2005).

Knowledge-intensive processes (KIP) are noted to be highly reliant on specialized expertise and knowledge. In fact, they can be considered as a class of organizational processes that constitute one or more activities that exhibit significant knowledge requirements for their effective enactment (Marjanovic and Seethamraju 2008). They also require an implicit or explicit information transformation by knowledge workers (Bhat et al. 2007). Knowledge management (KM) systems, which have been studied in great detail by researchers, have existed in organizations in one form or another. Knowledge management systems can be defined as information technology-based systems that provide support for knowledge creation, transfer, storage, retrieval, and application (Alavi and Leidner 2001). However, there are minimal design and deployment guidelines for situating KM systems particularly in the context of knowledge-intensive organizational work processes.

Process-based Knowledge Management (PKM) systems that can integrate knowledge management support with process co-ordination and automation systems to support knowledge-intensive processes are a potential solution to address this challenge (Abecker et al. 2000a; Bhat et al. 2007; Dustdar 2005; Kwan and Balasubramanian 2002; Remus and Schub 2003). The goal of PKM systems is to be able to support knowledge-intensive processes that exhibit high reliance on the knowledge and expertise of participants executing the activities. While several instances of process-based knowledge management systems have been proposed, for example case-based reasoning systems for claim handling, they are limited in their ability to handle different types of knowledge as well as in their ability to provide a comprehensive set of knowledge management functions including creation, transfer, storage, retrieval and application.

In this paper, we identify requirements and develop design guidelines supporting the development of PKM systems that can provide comprehensive knowledge management support in the context of a knowledge intensive process. We then review the extant literature in business process management and knowledge management and identify meta-requirements for a process-based knowledge management system. From a design science perspective, the central artifact we propose in this paper is the PKM design process that integrates various techniques that address the meta-requirements identified. The paper is organized as follows. In the next section, relevant research work from literature is discussed. Following this, the information systems design theory is discussed as the relevant methodology for this work. Next, the proposed design theory for PKM systems is presented followed by a discussion of future research work involving validation of the proposed design theory.

Relevant Work

Knowledge-intensive processes require significant knowledge support in efficient and effective execution of their activities (Tautz 2001). Their knowledge requirements are primarily satisfied through experiential and expert knowledge of organizational role members and thus the knowledge workers have a large impact on the outcome of KIP (Eppler et al. 1999). Additionally, such knowledge-intensive processes may exhibit other characteristics such as the need for currency of knowledge along with creativity and innovation in accomplishing the activities, steep learning curve for knowledge workers in acquiring requisite skills, numerous process-related decision possibilities, and contingency of activities on environmental factors (Eppler et al. 1999). Examples of knowledge-intensive processes include processes related to customer service or help desk, change management, responding to request for proposals, and incident management.

According to Eppler et al. (1999), organizational processes can be classified along two dimensions, namely knowledge intensity and process complexity. Knowledge intensity is characterized as discussed above, whereas

process complexity is characterized based on the number of activities involved, number of organizational role members involved and corresponding process coordination requirements, interdependencies between role members and activities, and whether the process changes (dynamic) or evolves (emergent) much over time. An organizational process may fall in one of four possible classes based on whether it is considered to have high or low process complexity and high or low knowledge intensity. Moore (2000) provides a similar framework in which the extent of knowledge sharing, collection, and reuse governs the extent of knowledge intensity in a process.

In this research, we focus primarily on the class of low process complexity and high knowledge intensity. In addition to the arguments made earlier, it is noted that knowledge management can potentially serve as a key strategy for the redesign of business processes (El Sawy and Josefek 2003). Using this strategy for enhancing the organization's knowledge creation and utilization capacity, seemingly simple organizational processes may be redesigned to provide significant competitive advantage for organizations in today's knowledge economy.

Literature review indicates that within the past decade, several researchers have emphasized the need to extend BPM systems to support knowledge flow in organizations (Abecker et al. 2000b; Nissen 2002). Even from a knowledge management perspective, process orientation is critical to providing task relevant knowledge in the context of an organization's operative business processes (Maier and Remus 2002). The KnowMore system, developed by Abecker et al. (2000a) adopts a workflow-based architecture for organizational memory information systems (Abecker et al. 1998), and uses a knowledge intensive task (KIT) specification to model the knowledge requirements of a workflow task. The knowledge in context (KIC) model, developed by Kwan and Balasubramanian (2002), extends the four perspectives (functional, organizational, informational, and behavioral) of a process model proposed by (Curtis et al. 1992) to derive the knowledge requirements of the process. The KIC model has been implemented in a workflow-based information system called the KnowledgeScope, the core components of which include Workflow Support Services, a Knowledge Application System and a Knowledge Repository. While these developments supporting integration of knowledge management functionalities in BPM systems are noteworthy, they lack presenting a generalized set of design guidelines for this class of systems.

Research Methodology

The design science research framework as proposed by Hevner et al. (2004) is used to guide the development of the proposed design process. The artifact proposed in this paper is the PKM design process which can be adopted as a method for developing process-based knowledge management systems. In applying the design science guidelines for developing the proposed artifact, we rely on a knowledge-base of knowledge management frameworks and techniques, and the information systems design theory proposed by Walls, Widemeyer, and El Sawy (1992) for integrating the knowledgebase into the proposed PKM design process. The information systems design theory (ISDT) approach, initially proposed by Walls et al. (1992) provides prescriptive design guidance for the development of design theories. Walls et al. (1992) suggest that a design theory is prescriptive and goal-oriented, as opposed to a predictive or explanatory natural science theory. A design theory is considered to relate to the design product as well as the design process.

Table 1 shows the important components of an ISDT. A set of meta-requirements for the design product are derived from relevant kernel theories. The design method for the artifact construction is governed by the design product meta-requirements as well as kernel theories, which may be possibly different than the design product kernel theories. The meta-requirements also guide the meta-design principles and artifacts for the design product, which are further tested using design product hypotheses to understand the extent to which the meta-requirements are actually met. Similarly, the design method hypotheses test whether or not the design method results in an artifact that is consistent with the meta-design.

In this work, we focus on the design process aspect of the design theory. The design product aspect is more relevant to commercial software packages in testing for their generality as well as to test whether they build upon kernel theories and meta-design principles. The design process aspect in the context of KIP addresses an important design problem in itself by prescribing a novel design method for PKM systems development. The proposed design method builds on relevant kernel theories as well as the meta-requirements of PKM systems.

Table 1. Components of Information Systems Design Theory (adapted from (Walls et al. 1992))	
Design Product	
Kernel theories	Theories from natural or social sciences governing design requirements
Meta-requirements	Describes a set of goals to which the theory applies
Meta-design	Describes a set of artifacts hypothesized to meet the meta-requirements
Testable design product hypotheses	Used to test whether the meta-design hypotheses satisfies the meta-requirements
Design Process	
Kernel theories	Theories from natural or social sciences governing design process itself
Design method	A description of procedure(s) for artifact construction
Testable design process hypotheses	Used to verify whether the design method results in an artifact which is consistent with the meta-design

A PKM Design Theory

This section presents the PKM design theory for designing Process-based Knowledge Management Systems. We begin by presenting the meta-requirements for a PKM system and then discuss the design process, kernel theories that form the basis of the design process, and the meta-design features of a process-based knowledge management system.

Meta Requirements for a PKM System

A key requirement for any knowledge management system is to support one or more organizational knowledge management processes including knowledge creation, knowledge storage and retrieval, knowledge transfer, and knowledge application (Alavi and Leidner 2001). Knowledge application in the context of knowledge intensive processes is enabled through the provisioning of relevant knowledge to a knowledge worker. Therefore a PKM system needs to be able to support knowledge workers in task execution by providing the requisite knowledge.

MR1: A PKMS should support knowledge worker in task execution by providing requisite knowledge.

The flow of knowledge in organizations is tightly integrated with and complementary to the flow of work (Nissen 2002). Process-based knowledge management systems, which are designed to support knowledge intensive structured processes, also need to be integrated with process co-ordinations systems to effectively manage the knowledge needs within such processes.

MR2: A PKMS should be integrated with work process co-ordination systems

Alavi and Leidner (2001) state that the transfer of knowledge to where it is required is an important component of knowledge management, given the distributed nature of organizational cognition. Knowledge transfer in organizations occurs at various levels including between individuals, groups and the enterprise, and such transfers are key strategies for managing knowledge and human capital in the context of business processes (El Sawy and Josefek 2003). Knowledge transfers are often mediated through repositories, and storage and retrieval mechanisms that add to an organizational memory. Correspondingly, the meta-requirements for a PKMS include the following:

MR3: A PKMS should enable transfer of knowledge from individual to enterprise

MR4: A PKMS should enable transfer of knowledge from enterprise to individual

MR5: A PKMS should enable exchange of knowledge among multiple individuals and the enterprise

Beyond supporting knowledge application, knowledge transfer, and knowledge storage and retrieval processes, a process-based knowledge management systems should create new knowledge that can help improve the business process or create improved and more valuable outcomes from the business processes (El Sawy and Josefek 2003).

MR6: PKMS should generate additional values that help improves process and process outcomes

It is imperative that a process-based knowledge management system also responds to the changing environment and knowledge needs within a knowledge intensive process. Specifically, since knowledge needs are highly dependent on user background and expertise, a PKMS should enable personalized delivery of knowledge to process participant. Personalization can prevent overload, provide additional value for process participants and increase process execution speed (El Sawy and Josefek 2003).

MR7: Personalize: Personalize to participant

Design Process

The design process that can be used to develop artifacts that satisfy the above mentioned meta-requirements is outlined in this Section. In order to illustrate the design process and demonstrate the feasibility and applicability of each of the design steps within the process, we use example knowledge intensive process called RFP-response process. The RFP response process is typical of the sales processes of large consulting firms and knowledge-based organizations. It is a structured and consistently repeated process consisting of several knowledge intensive tasks. A simplified version of the RFP Response sales process is shown in Figure 1. A knowledge intensive process such as the RFP response process can greatly benefit from a process-based knowledge management system that can support process participant in executing their tasks, help knowledge transfer across participants and knowledge reuse across process instances, and create new knowledge based products. In the rest of this section, we describe our design process use elements of the RFP response process to illustrate the feasibility and working of the individual design steps.
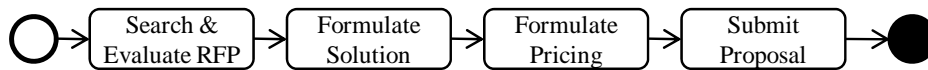

Figure 1. A Simplified RFP Response Process

The design process consists of 7 different design steps. Corresponding to each design step, we describe the objective of the design step, the kernel theories underlying the design step, the output design document and its purpose, and a discussion on the meta-requirements addressed by the particular design step.

Step 1: Develop business process model

During the first step of the design process, a process model of the underlying knowledge intensive business process is developed. The objective of this design step is to identify the tasks in the underlying business process, the dependencies among the tasks and roles and users performing the tasks. The kernel theories that govern this design step include process and workflow modeling methods such as Petri nets (van der Aalst 1998) and UML activity diagrams (Dumas and Hofstede 2001). Other relevant modeling methods proposed include the CommonKADS methodology (Schreiber et al. 1999) and the knowledge intensive task specification (Abecker et al. 1998). However these are more suited to model task knowledge requirements than process models. The output design document for this step is an activity diagram such as in Figure 1 describing the tasks, task sequence and a description of tasks along with roles assigned to perform the tasks. The purpose of the design document is to help analyze the relationships between knowledge intensive tasks when identified, in context of other tasks and the overall business goal. The output of this design step helps satisfy meta-requirements *MR2* by situating the PKMS Artifact in a business process model and thus enabling the invocation of the relevant PKMS components within the context of a workflow system. It also helps satisfy meta-requirement *MR6* by documenting process knowledge in the form of a process model.

Step 2: Identify knowledge intensity of each task in the process model

This design step is aimed at identifying knowledge intensity of each task within a business process. Eppler et al.'s (1999) framework is used as the underlying kernel theory governing this design step. Eppler et al. (1999) identify six attributes for describing knowledge intensity. The attributes include contingency, decision scope, agent innovation, half-life, agent impact and learning time. A knowledge intensive task is defined as requiring high agent innovation, involving multiple decision paths, contingent upon numerous eventualities and being highly dependent on agent actions. They are also characterized by long learning time to perform the task and lower knowledge half-life, where knowledge quickly becomes obsolete. In this design step, each task in the business process need to be rated on the six attributes to estimate their knowledge intensity. Estimating the ratings is a part of the requirements gathering process and can be based on expert opinion and customer input. The tasks are then ranked and prioritized based on their knowledge intensity.

In order to illustrate the working of this technique, consider the RFP response process. In this process, the *formulate pricing* and *submit proposal* can be relatively straight forward tasks involving fewer decision paths, lesser agent innovation and learning time. However, tasks *Search & Evaluate RFP* and *Formulate Solution* may require higher learning times, decision paths and are highly dependent on agent actions. The design document output through this design step includes a prioritized list of tasks based on their knowledge intensity. The output design document helps identify knowledge intensive tasks that require knowledge management support and help prioritize PKM features and system development. This design steps helps satisfy meta-requirement *MR1* by identifying tasks that have heavy knowledge requirements and thus enabling the development of systems that can provide knowledge support in the context of those tasks. In some instances, the knowledge intensity of a task can be better estimated by identifying the knowledge requirements of a task, which is the focus of design step 3. In such cases design step 3 can be performed prior to estimating the knowledge intensity of a task.

Step 3: Identify knowledge requirements for each knowledge intensive task

This design step is aimed at identifying knowledge requirements for the knowledge intensive tasks identified in the previous step. While process knowledge is mostly procedural and knowledge related to particular instances of a workflow may be declarative in nature, we rely on multiple taxonomies of knowledge types to ensure flexibility of the design process as the knowledge required to complete a task may be of different types. The use of multiple taxonomies of knowledge types in prescribing the design process also enables its extensibility to support innovative knowledge management solutions that may arise due to evolution of technology. We rely upon three different taxonomies of knowledge types to capture the different aspects of task knowledge. We use the tacit-explicit classification of knowledge (Nonaka 1994; Polanyi 1962) to identify task related knowledge that is documented and as well as knowledge that is rooted in experience and is in the form of an individual's mental models. Next, we classify task knowledge into procedural (know how) and declarative (know about) categories. This categorization helps identify appropriate knowledge representation mechanisms to store and transfer task knowledge. We then identify general knowledge as well as contextually and technically specific knowledge. Such a categorization helps identify knowledge reuse scenarios and appropriate knowledge sources (Markus 2001). For example, general and technical specific knowledge can be obtained from external sources whereas contextually specific knowledge is limited to internal sources.

The design document output through this design step includes a task knowledge requirements specification that helps determine knowledge requirements of a task. For example, knowledge requirement specification for *Search and Evaluate RFP* would identify under explicit and declarative categories knowledge such as funding agencies as general knowledge, organizational capabilities as contextual knowledge, and hardware and software specifications as relevant technical knowledge. Similarly, tacit declarative knowledge relevant to the task could be identified as success probabilities with various agencies as general knowledge, comparative evaluation of the funding opportunities in the context of the organization as contextual knowledge and knowledge of the robustness and reliability of the technical infrastructure as technical knowledge. In terms of procedural knowledge, the task specific knowledge could be identified as the process for evaluating and RFP and the process for retrieving organizational capabilities.

Step 4: Identify knowledge sources in organization and outside

The objective of design step 4 is to identify different sources of knowledge in an organization as well as external sources of knowledge. Several researchers have proposed alternative taxonomies of organizational knowledge that can be used to identify organizational knowledge sources. Holsapple and Joshi (2004) classify organizational

knowledge into schematic knowledge and content knowledge. Becerra-Fernandez and Sabherwal (2001) develop a classification of knowledge reservoirs consisting of people, artifacts and organizational entities. The design document output through this step includes a knowledge map describing sources of knowledge identified in knowledge requirements specification. This design document helps identify organizational knowledge sources and helps satisfy meta-requirements MR1, MR3 and MR4 by identifying knowledge sources that can satisfy task knowledge requirements, and source and recipient end points for knowledge transfer between individuals and an enterprise knowledge reservoir.

Step 5: Assess knowledge reuse

Building on the previous step, this design step identifies knowledge producers and users in an organization. The kernel theory that forms the basis of this design step is the knowledge reuse framework proposed by Markus (2001). This design step involves identifying task specific knowledge creation and reuse scenarios and classification into 4 different knowledge reuse classifications that include shared work producers, shared work practitioners, expertise seeking novices, and secondary knowledge miners. Based on organizational procedures and context, the Evaluate RFP task of the RFP response process can be classified as a "Shared work producers" knowledge reuse situation when the task is jointly performed by a diverse or a homogeneous group of participants, whereas it can be classified into a "shared work practitioners" scenario when several instances of the Evaluate RFP task are independently performed across the organization by different knowledge workers. The output design document for this design step includes a listing of task-specific knowledge creation and reuse scenarios. This design step helps identify and develop knowledge flows within an organization in support of the knowledge intensive process, thus satisfying meta-requirements MR3, MR4 and MR5.

Step 6: Develop task-user knowledge profile

This design step aims to develop an instrument to identify knowledge gap between task knowledge requirements and user knowledge. A knowledge intensive task specification proposed by Abecker (1998) that can be used to specify the task-specific user knowledge needs. The KIT specification captures information needs of a task, preconditions, and information inputs to the tasks and information outputs from the task. The output design document is a task specific user profiling template to capture task-specific user knowledge. Such a profile can be used in a user profiling mechanism to infer user knowledge requirements and user interests specific to task over time. This design step helps satisfy meta-requirements MR1 and MR7 by personalizing knowledge delivery based on task context as well as user knowledge needs.

Step 7: Design task-specific knowledge management agents

The last design step utilizes the design documents to develop task specific KM support agents that integrate with a business process management system to form a process-based knowledge management system. It should be noted here that the task specific knowledge management agents are components that connect the underlying knowledge management infrastructure with the specific needs of a task and the knowledge worker. While the task-specific KM support agents risk obsolescence when the supported tasks are no longer executed in a business process, the underlying knowledge management infrastructure can continue to support a wide variety of tasks and new task specific KM support agents. The task-specific KM support agents that can be designed include knowledge application agents, knowledge creation agents, knowledge storage and retrieval agents, and knowledge transfer agents.

By mapping the task knowledge characteristics and source knowledge characteristics identified in steps 3 and 4 to a catalog of knowledge management techniques and an underlying knowledge management infrastructure, the task specific knowledge support agents can be developed. For example, procedural knowledge can be stored as and provided through expert systems and knowledge based systems whereas declarative knowledge can be stored as and provided through database systems. Similarly, socialization based knowledge management techniques can be used to transfer tacit knowledge, whereas document repositories can be used to transfer explicit knowledge. A mapping describing the relationship between the various design steps and the meta-requirements identified earlier in this paper is shown in Table 2.

Table 2. Meta-requirements and Supporting Design Steps	
Meta-requirement	**Supporting Design Steps**
MR1	MR1 is supported by design steps D2, D3, D4, D6, and D7 through identification of knowledge intensive tasks (D2), their knowledge requirements (D3), knowledge sources that can satisfy the requirements (D4), identifying knowledge workers that perform the tasks and modeling their background knowledge (D6) and then identifying appropriate knowledge support services and agents (D7).
MR2	MR2 is supported by design step 1 (D1) that model the underlying business process that connects the knowledge intensive tasks.
MR3	MR3 is supported by design steps D3, D4, D5, D6 and D7 by identifying task specific knowledge requirements (D3) and user knowledge requirements (D6), relevant knowledge sources (D4), situations in which such knowledge can be reused (D5), and developing the relevant knowledge support services and agents to promote knowledge reuse (D7).
MR4	MR4 is supported by design steps D4, D5, and D7 by identifying organizational knowledge sources (D4), situations in which such knowledge can be reused (D5), and developing the relevant knowledge support services and agents to promote knowledge reuse (D7).
MR5	MR5 is supported by design steps D3, D5, and D7 by identifying task specific knowledge requirements (D3), situations in which such knowledge can be reused (D5), and developing the relevant knowledge support services and agents to promote knowledge reuse (D7).
MR6	MR6 is supported by design steps D1 and D7 by documenting process knowledge (D1) and developing the relevant knowledge support services and agents to promote knowledge reuse (D7).
MR7	MR7 is supported by design steps D6, D4 and D7 by identifying task specific user knowledge requirements (D6), relevant knowledge sources (D4) and developing the relevant knowledge support services and agents to promote knowledge reuse (D7).

Conclusion and Future Work

Supporting knowledge-intensive processes effectively to gain competitive advantage as well as to manage organizational knowledge and human resources in an optimal manner is important in today's knowledge economy than ever before. In that regard, this article has contributed by identifying the need for a design theory for process-based knowledge management systems, identifying key kernel theories to guide the design and development of PKM systems, and synthesizing various kernel theories to propose a comprehensive design theory for PKM systems. This is a research-in-progress and research efforts are currently focused on demonstrating the feasibility and evaluating the design process for PKM systems (Sarnikar and Deokar 2009).

In order to evaluate the proposed design theory, an experimental study involving graduate students enrolled in an Information Systems program is being planned. The study is designed to test the following design theory hypotheses: (1) it is feasible to design a specific PKM system based on the PKM design process. (2) A design for a specific PKM system based on the combination of the PKM design process and Object-Oriented Analysis and Design techniques will be judged by the user to be superior to one designed using Object-Oriented Analysis and Design techniques alone. (3) A design for a specific PKM system based on the combination of the PKM design process and Structured Analysis and Design techniques will be judged by the user to be superior to one designed using Structured Analysis and Design techniques alone. In this study, both experimental and control group will be asked to develop a meta-design, consisting of design artifacts, for a PKM system that would address these requirements. The experimental group uses the proposed design method, while the control group uses conventional systems analysis and design principles. The proposed design method, once validated, can serve as a design guide for system analysts and developers to build PKM systems that can effectively support knowledge-intensive processes.

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