Knowledge Flow Modeling and Analysis with Focus on Enabling Actions and Decisions within the Business Process

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Abstract

*This paper examines current approaches to knowledge flow analysis and modeling and their ability to drive a shared understanding among business managers, knowledge managers, and knowledge engineers. It presents Knowledge Flow Analysis and Modeling (KFAM) as an alternative approach anchored in the position that knowledge enables actions and decisions and that knowledge flows include those behaviors through which knowledge is acquired, retained, and transferred within an organization, to enable the actions and decisions that comprise the business process. Modeling and analytical methods are described, along with antidotal accounts of the application of these methods in real-world situations covering a span of over 10 years. The paper concludes with a number of lessons-learned, recommendations, and directions for further developmen*t.

1. Introduction

This paper describes a set of practical methods for Knowledge Flow Analysis and Modeling (KFAM) that bridge the knowledge engineering and business process engineering domains. It builds upon the authors' experience and previous work and on that of researchers in the fields of systems dynamics [1], [10], [11], [13], [16], knowledge flow dynamics [4], [8], [19], [24], [25], [26], [33], [34], [38], and business process modeling [9], [15], [18], [36], [37]. As practitioners, the authors developed these methods as a way to address critical gaps between theory and practice and to illuminate often-overlooked aspects of how knowledge enables organizational behaviors.

The authors have found this approach to be effective at driving shared understanding of the targeted knowledge flows among business managers, knowledge managers, and knowledge engineers. This shared understanding includes the relationships between business processes and how the acquisition, retention, transfer, and use of knowledge enable the actions and decisions within those processes. The authors see this type of shared understanding as critical in identifying the methods, practices, tools, and techniques best suited for engineering the knowledge flows needed to support the operational needs of the organization.

In Section 2, we describe the problems and issues that drove the development of these methods. In Section 3 we survey established approaches to knowledge flow modeling and perceived gaps. Sections 4 through 6 provide an overview of the conceptual foundations of the KFAM approach and the KFAM modeling and analysis methodologies. The closing sections recount the experience gained through the use of KFAM in the field, how that experience reflects on the ability for KFAM to address the recognized gaps, lessons learned during its development and testing, and directions for future development. As appropriate the authors attempt to provide an accounting of the various theoretical influences informing the design and evolution of the KFAM approach.

2. The Need for Shared Understanding

Attempts to improve knowledge flows typically depend on the ability to align the perspectives of a wide variety of stakeholders, most notably business managers, knowledge managers, and knowledge engineers. Many knowledge management initiatives have been hampered when stakeholders from these various perspectives attempt to leverage incomplete, contradictory, and even divergent understandings of the organizations performance targets and supporting knowledge flows. The cornerstone of this shared understanding being that knowledge enables actions and decisions and that *knowledge flows* include four critical behaviors; those through which that knowledge becomes available to the organization (acquisition), those involved in retaining that knowledge, the transfer of knowledge within the organization, and it use in enabling the actions and decisions that comprise the business process [21].

The business manager's role is to influence the behaviors of a group of one or more agents toward accomplishing some set of desired goals, or objectives. Those with a business management perspective understand that the significance of an activity is not in the activity itself, but in its contribution to performance. It is common for multiple business managers with distinct perspectives to be impacted by a given knowledge flow.

Knowledge management is concerned with the knowledge needs of the enterprise. We expect knowledge managers to conduct the research necessary to understand the specific knowledge that is needed to enable business-critical decisions and actions. They regularly take a key role in enterprise design, translating the enterprise's knowledge requirements into knowledge management policies. It is to the knowledge managers that the users should go with their "needs to know".

Knowledge engineers use tools and methods from a range of disciplines such as data and information representation, encoding methodologies, data repositories, work flow management, and groupware technologies to develop methods for satisfying the requirements established by the knowledge manager. They also establish the processes by which knowledge requests are examined, information assembled, and knowledge returned to the requester.

These three roles, which we will refer to hereafter simply as the KM Leadership Team, need straightforward and easy to implement ways to reach shared understanding of the business processes and issues that they must work together to address. Analysis and modeling frameworks have been found to be effective mechanisms for driving needed consensus, but the task of selecting an appropriate framework can be a daunting one.

The resulting models should not only make sense, but provide useful insights and facilitate consensus across all of the targeted stakeholders. This is a challenge, because, by definition, modeling provides a simplified picture of reality, highlighting what is perceived as important from a one perspective and excluding the details that might be important from another perspective.

3. Current Practice

Over the last 10 years, a number of approaches to knowledge flow modeling have been proposed. As practitioners, our specific interest is in techniques which can be readily applied in the workplace to develop a shared understanding within the KM Leadership Team. Based on our experience, the techniques that came closest to meeting our needs tended to focus either on the business process or on knowledge codification. This section provides a brief over-view of these two dominate approaches, summarizes their limitations, and requirements that influenced the development of the KFAM approach.

3.1 Business Process Focus

A business process is a set of logically related business activities that combine to deliver something of value (e.g. products, goods, services or information) to a customer. Business processes can include multiple concurrent activities, each with a series of discrete events, composed of multiple activities, performed by multiple components (distributed systems) [31]. These same attributes can also be seen in knowledge flows. While there have been numerous methods advances for modeling workflow and business processes, one reoccurring characteristic is the adaption of the basic Petri net. [17]

Petri nets provide a set of formal semantics [8], [37] and graphical notation [18] for specifying and analyzing systems with many of these same characteristics. Since Zisman [39] introduced the use of Petri nets to model workflows, numerous authors, including Ellis [8], Ellis and Nutt [9], Merz et al. [18], and van der Aalst and van Hee [37] among others. Space does not permit a full description of the evolution of these modeling methods, but it is important to note that Petri nets are well suited to support a task-oriented view where the task rather than participant serves as a primary ordering concept. Holt [15] suggests as a basic condition for Petri nets to be useful for workflow modeling is that all workflow parts can be described as well-defined pieces of reality.

3.2. Knowledge Codification Focus

One of the more prevalent schools of thought with regard to Knowledge flow modeling stems from the SECI model developed by Nonaka, and Takeuchi [27] and the creation of knowledge through the interaction between tacit and explicit knowledge. The SECI model addresses four primary behaviors; socialization, externalization, combination, and internalization. Socialization is the process of creating new tacit knowledge by individuals through sharing experience-based tacit knowledge. Through externalization, tacit knowledge is articulated and converting it into explicit knowledge. The process of combining explicit knowledge through restructuring and aggregating creates new explicit knowledge. Finally, through reflection explicit knowledge becomes internalized and embodied as tacit knowledge.

Nissen [24], [25] extended the SECI framework creating a four dimensional model for representing and visualizing the dynamics of knowledge flows, knowledge transfer, and the conversion of data to information and information to knowledge. While not tied to the SECI framework, the conceptualization of knowledge flows as the transformation of data to information, information to knowledge can also be seen in Spiegler [34], but with the inclusion of a double hierarchy in which knowledge can also be converted to data. Naeve [20] integrates the SECI framework and conceptual browsing and then applies the resulting Unified Language Modeling (a dialect of the Unified Modeling Language) to model the concept of a Human Semantic Web (HSW).

Social network theory views knowledge flows as a phenomena stemming from knowledge complexity and the density of social networks. Sorenson, Rivkin, and Fleming [33] took the perspective that in a flow of knowledge from one party to another, the recipient actively attempts to fill gaps in the transmission based on the perceived need to correct transmission errors. Their approach to modeling knowledge flows of this type combine aspects of social network theory with a view of knowledge transfer as a search process. Collins [5] chose an approach based more on the tools of ethnographic research, business anthropology, and cultural consensus analysis.

Nissen, Kamel, and Sengupta [24], [26] also report on approaches to knowledge flow modeling with roots in artificial intelligence (AI), classic knowledge engineering and knowledge-based system design (KBS). These methods have a strong emphasis on the capture, formalization and application of strong domain knowledge.

Yoo, et al. [38] describe an approach to business process re-design in which the organizing perspective is one where knowledge is both an input and an output of the business processes making the flow of knowledge an inseparable aspect of the business processes. In this approach, a combination of techniques, including knowledge mapping and knowledge profiling, are used to identify, and subsequently optimize knowledge flows.

3.3. Limitations and Requirements

To fully understand any business process, one should also understand the way knowledge is made available to enable the actions and decisions within the process. Each of the above mentioned approaches may be informative to the knowledge manager or knowledge engineer who has an understanding of the underlying theory. However, Carter [3] argues, that not only are they less informative to the business manger, but may actually impede the collaboration needed for a successful KM solution. This argument is supported by the meta-synthesis of 287 pieces of KM literature developed by Griffiths [14] to determine why KM appeared to be under performing. His report ended with three basic views; a lack of satisfaction on the part of the practitioner, a gap in the literature and blockage in the flow between academic and practitioner, and an uncommon language, which results in a lack of definition and focus for the process [23, p. 732]. Carter further argues that business leaders do not have the time, or in many cases, the inclination to sort through theories when their direct need is to implement a solution for their immediate business problem.

Both the business process and knowledge codification centric approaches lack ways to adequately account for and model the impact of implicit knowledge in enabling actions and decisions. Implicit knowledge and the companion concept of implicit learning are well researched topics within the behavioral and cognitive sciences communities. However, implicit knowledge has only more recently become a topic of growing interest within the knowledge management community.

As expressed in [7], [32], and elsewhere, the cognitive and behavioral perspective defines the difference between explicit and tacit knowledge based on what is knowable via the conscious recollection; conscious recollection is a required aspect of explicit knowledge but not of implicit knowledge. Within the KM domain, the distinction between explicit and tacit knowledge stems from the degree of codification. As expressed by Polanyi, explicit knowledge is that which is easily codified and tacit knowledge is that which one can know but which cannot be expressed or codified [29], [30].

However, Polanyi also says that implicit knowledge can be converted to explicit form and it may be for this reason that within KM literature, this distinction between tacit knowledge is often vague and ambiguous [19] . Compounding the problem is the fact that tacit knowledge is treated as synonymous with implicit knowledge [6]. There is however evidence of a growing recognition within the KM community that there is a middle ground between the explicit and tacit. [12] Refers to this as an organization’s implicit knowledge; tacit knowledge that, with dedicated and focused efforts, can be transformed into explicit knowledge.

Within the context of this paper, the authors extend the definition provided by [7] and define an implicit knowledge artifact as a knowledge artifact whose meaning is dependent on additional supporting facts (referential knowledge) that is necessary for the implicit artifact to have the meaning it has. The meaning of an implicit knowledge artifact is dependent on one or more referential knowledge artifacts.

To overcome these limitations and provide a means to more fully address the need to quickly and reliably establish a shared semantic framework for KM Leadership Team, the KFAM approach was designed to fill the gap between theory and practice and illuminate normally overlooked aspects of organizational behavior.

A viable solution should meet the following criteria:

- Ease of use: The analysis and modeling method should be usable with minimal training. It should not require, but be supportable by off-the-shelf modeling tools.
- Behavioral support: The analysis and modeling method should be able to identify knowledge flows and the actions and decisions they enable. It should also be able to identify the four key behaviors within the knowledge flows and provide the ability to analyze and model those behaviors, the artifacts through which the knowledge is conveyed, and the agents that perform the actions, including their role as a path for enabling knowledge.
- Scalability: The analysis and modeling method should be able to represent knowledge flows from the individual process to enterprise level. This should be done without the need to distinguish between the cognitive and physical aspects of knowledge artifacts, but still retain the ability to identify and capture those details if the situation warrants.

In following sections we present KFAM as an alternative approach to knowledge flow modeling and analysis. In Section 4 we introduce the fundamental concepts upon the KFAM approach followed by an overview of the modeling methodology in Section 5 and the basic analytical methods in Section 6. In Section 7 we highlight the experience we and other earlier adopters have gained through application and field testing and in Section 8 summarize how this experience relates the usability, behavioral, and scalability criteria, some of the key lessons learned in the process, and directions for further exploration and development.

4. KFAM Perspective

It is vital that business leaders know what knowledge is needed, where it is needed and how to use it when it is needed to make decisions or take actions [3]. The authors have found that an approach to knowledge flow analysis and modeling that focuses on Knowledge Utilization — how knowledge is used to enable actions and decisions — solves many of the problems associated with the business processes and knowledge codification-based approaches described, above.

KFAM is based on a number of conceptual foundations, which are described in this section: Knowledge Utilization Events, The General Knowledge Model, Agent types, and Knowledge artifact types. For more information on agents, artifacts, transformations, and the other conceptual foundations of KFAM described in this section, see Newman 2003[21].

4.1 General Knowledge Model

The General Knowledge Model (GKM) [21] shown in Figure 1 organizes the four classes of behaviors of primary interest when analyzing knowledge flows. Collectively, these four behaviors (knowledge acquisition, knowledge retention, knowledge transfer, and knowledge utilization) determine the meaning (semantics) associated with the knowledge artifacts that flow between them.

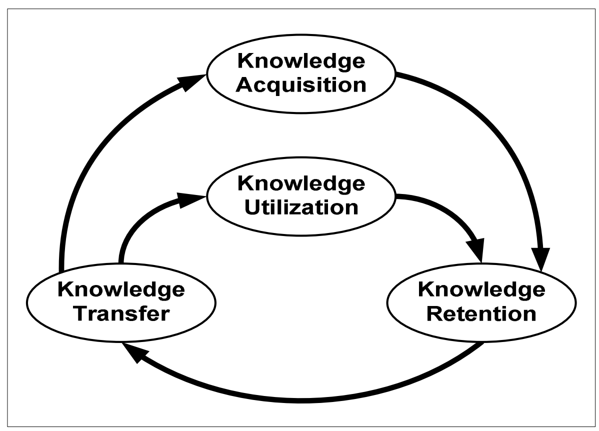

Figure 1 The General Knowledge Model

Knowledge acquisition includes those activities associated with the entry of new knowledge into the system, and includes knowledge development, discovery and capture. Knowledge retention includes the activities that preserve knowledge and allow it to remain in the system once introduced. It also includes those activities that maintain the viability of knowledge within the organization. Knowledge transfer refers to the activities associated with the flow of knowledge from one party to another. This includes communication, translation, conversion, filtering and rendering. Knowledge Utilization (a.k.a., the Knowledge Utilization Event or KU) includes the activities and events connected with the application of knowledge to business processes. As such, it serves as the bridge between the business process model and the knowledge flow model. The General Knowledge Model sequences these behaviors in a deterministic fashion. The model is valuable precisely because it relates the individual, highly dynamic behaviors and processes to general activity areas and, by association, to each other.

4.2 Knowledge Artifacts

Knowledge artifacts are the memories, norms, values, and other things that represent the inputs to, and products of, the knowledge-enabled activities of agents. When we speak of knowledge artifacts within the context of knowledge flows, we are actually making a simultaneous reference to two important entities. The first is the physical knowledge artifact, which serves as a representation of the associated cognitive knowledge artifact. The second is the cognitive knowledge artifact that makes up our awareness and understanding of a particular aspect of our real or meta-physical world. As discussed earlier in our review of gaps in the existing approaches to knowledge flow modeling, knowledge artifacts whether physical or cognitive, can be explicit, implicit, or tacit. Where they fall within this continuum will have a significant impact on how it relates to other elements of the knowledge flow.

This simplified concept of the *knowledge artifact* serves to reduce the complexity of the initial analysis and allow the analysis of the subtle, and often contentious, distinctions between the interpretation, codification, contextualization, and the aspirational and behavioral associated with a knowledge artifact to be addressed if an when appropriate.

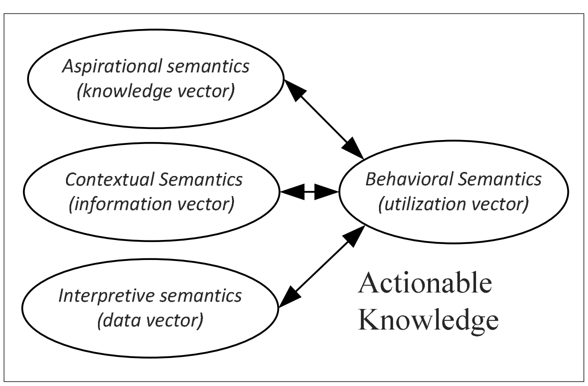

Figure 2 The Semantic Vector Model

Another area of contention is the distinctions among data, information, and knowledge. Again, the generalized concept of the knowledge artifact allows these distinctions to be avoided until such a time as they become important, such as when designing semantic structures for metadata codification.

Figure 2 provides a visual depiction of how different sets of semantic properties can be associated data, information, knowledge, and the resulting KUs. The authors have found that these semantic distinctions are somewhat more concrete and more useful than trying to drive consensus on the boundaries between data, information, and knowledge.

4.3 Agents

Agents are the active components of knowledge flows and have specific characteristics that allow them to interact differently with different types of artifacts. For instance: the individual agent can deal with tacit artifacts, whereas the automated agent cannot. The collective agent can retain knowledge beyond the life of individual agents. Automated agents can perform many types of transformations on explicit artifacts much faster and with a greater degree of repeatability than can individual agents.

5. Knowledge Flow Modeling

KFAM Models extend IDEF0 formats to show the relationships between the agents, artifacts, and events that produce a specific outcome. The authors have chosen to do this by extending existing business process modeling techniques to and highlight the role of knowledge into enabling the actions and decisions which comprise business processes.

The authors chose the IDEF0 form as the bases for KFAM because of the prevalence and familiarity to those in the business and engineering communities. In the IDEF0 modeling language (Figure 3), each box represents a single activity (task/action or decision) and the arrows entering and leaving the box represent its inputs, outputs, controls, and mechanisms.

Figure 4 shows how the IDEF0 graphical conventions have been adapted for knowledge flow modeling. The shaded box representing the activity in IDEF0 now represents the more abstract Knowledge Utilization Event. The arrows that represent knowledge artifacts have been emphasized. Knowledge artifacts are further segmented by role. Specifically: Input knowledge artifacts are those that are directly transformed by the KU. Resulting Knowledge Artifacts are those that are produced by the KU.

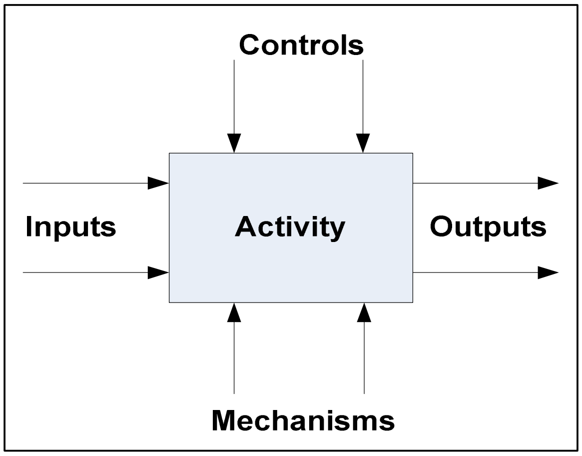

Figure 3: IDEF0 Model

Enabling Knowledge Artifacts are those that are not directly transformed but are required for the transform to be successful. Controlling Knowledge Artifacts are those that constrain behavior (e.g., policies and procedures). KSAs are the knowledge, skills, and abilities that agents provide to the transformation through execution. The agents that perform the KU are represented by boxes with rounded corners. They are associated with a KU as resources and serve as the conduit for the agent specific KSAs

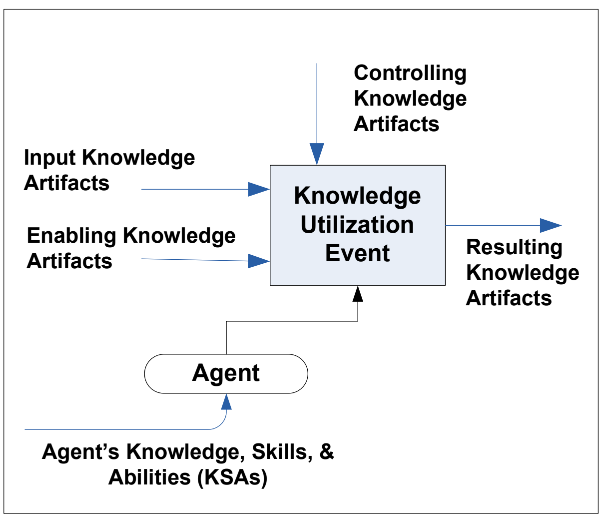

Figure 4: KFAM Model's KU Event Process Element

Most, if not all IDEF0 conventions for identifying and numbering processes, activities, sub-processes, and sub-activities to help link diagrams together and to make the diagrams more readable can be applied to KFAM models. To that end, while well developed knowledge flow models can make a significant contribution toward a shared understanding within the KM Leadership team, their full value is comes from their contribution to subsequent analysis.

6. Knowledge Flow Analysis

The purpose of knowledge flow analysis is to isolate and identify problems and ways to resolve such things as missing knowledge flow behaviors, agent and artifact dependencies, and semantic alignment. KFAM models support this by providing the necessary context to illuminate patterns, drivers, and potential control points. KFAM analysis principles and processes support alignment within the KM Leadership Team by address the interests of all three stakeholder groups and affiliates and maintaining a consistent focus on organizational behavior.

Though experience, we have found that the analysis process can be made more productive by following a few basic guidelines. First is that the processes and issues being examined are often very complex. It can be very tempting to start with a few knowledge flow elements and describe them in fine detail, but high-level models are usually easier to understand across the broad range of stakeholders and more effective at driving consensus. Even high-level analysis can dramatically increase transparency – illuminating previously hidden patterns, facilitating the identification of important issues, and providing the new insights that trigger the identification and design of better solutions. When these new understandings are nurtured and used to drive iterations of the models, the overall analysis and modeling initiative can be far more efficient and effective than when highly-detailed models are developed in isolation. KFAM treats analysis as an ongoing activity, starting with initial planning and continuing through the development and refinement of the knowledge flow models.

6.1 KFAM Planning Activities

The authors' suggest the following questions be used to identify the goals driving the analysis and modeling initiative and articulate actionable strategies for realizing those goals. Is the purpose of the initiative to inform knowledge alignment, impacting business strategy and/or knowledge strategy? Is it to support execution of a defined strategy, impacting knowledge system strategies and/or knowledge engineering activities? Is the initiative to solve specific problems, identify potential issues, assess risk, or look for opportunities for improvement? Is it to support the design of new processes and/or systems?

Once the business problem(s) have been identified and prioritized, they should be clearly stated in the form of one or more business questions that will focus the analysis and define the scope of the resulting models. These focus questions drive the identification of project success criteria. The authors suggest the use of such questions as: What information is required to answer the focus questions? Who will be informed with each piece of information? Does the audience have any conceptual preferences or biases which should influence how the information is organized and presented for delivery? What data, metadata, and information resources will be needed to feed the analysis and modeling processes?

The planning activities also need to address whether there is, or will be sufficient access to personnel and other organizational knowledge resources critical to project success. Answering the following questions can help make that determination. How much access will there be to subject matter experts? Who will be on the core team? What other experts will be made available? What's the cultural dynamic? Is participation seen as supportive or detrimental to other organizational goals? Will participation of the extended community be at a level to support tacit knowledge exchange or will the effort be effectively "quarantined?"

To ease the transition from the business prospective to the knowledge management and knowledge engineering perspectives as well as provide continuity and traceability over the effort, the authors strongly suggest that the planning activities include the development, or validation of a set of IDEF0 business process models covering those areas of the business process of specific concern. [28]

Just as analysis and modeling should be iterative, based on organizational needs and cultural preferences, various planning activities may need to be repeated. This often occurs when the knowledge flow analysis drives significant changes to scope or identifies strategic issues or opportunities that change the initiatives focus or priorities.

6.2 Development and Refinement of Models

The authors suggest that the development of the knowledge flow model focus on those activities specific to meeting the business objectives indentified in the planning phase, drilling down to deconstructing and refining them as necessary to expose the underlying knowledge flows.

Initial modeling and analysis should be able to identify the agent and artifact dependencies for each KU. Questions like the following can help in that process: What agent(s) perform the behavior? In addition to the knowledge artifacts (inputs and outputs) that are transformed by the KU, what other knowledge artifacts are required to enable the transformation?

After initial models of sufficient scope have been developed, the analysis and modeling typically shifts to more in-depth examination of the Knowledge Utilization events and the agents and knowledge artifacts that support them. Ideally, the specific refinements will be informed by lessons learned from the initial models.

To ensure that the model is at an appropriate level of granularity it is often helpful to look at the agent(s) performing each KU and consider questions such as: Do multiple agents perform a given KU and if so, is this because the activity is truly collaborative, or does it consolidate multiple KUs and hand-offs between agents? Does the model answer the focus questions, as is, or should these fine-grained KUs be broken out separately? Would the additional details make the model less usable?

It is also important to review the model to make sure that the knowledge artifacts are correctly mapped. Input artifacts should be transformed into the resulting knowledge artifacts. Enabling knowledge artifacts, though not transformed, should be required for the transform to be successful. Controlling knowledge artifacts should constrain behavior (e.g., policies and procedures). The KSAs (knowledge, skills, and abilities) that agents provide to the transformation

Another set of refinements involves characterizing the KUs, agents, and knowledge artifacts. KUs are characterized by their location within the GKM [23]. Doing so addresses the question; does the activity support the full range of knowledge flow behaviors? If the KU does not cleanly fit one of these categories, it likely warrants further deconstruction.

Additional questions that help identify areas for refinement include; is each agent an individual agent, collective agent, or automated agent and are the knowledge artifacts explicit, implicit, or tacit? Knowledge artifacts can also be characterized as data, information, or knowledge, but such efforts are usually problematic, as consensus is hard to reach and often fragile, subject to constant second guessing. When designing semantic structures for metadata codification, the authors have found value in making distinctions between data, information, and knowledge. Semantic properties can be categorized, based on the portions of the Semantic Vector Model (Figure 2) that they describe.

The models are typically extended by performing KU analysis [22] on each of the actions, deconstructing them into finer-grained KUs and updating the models based on the results of the KU analysis.

The models can also be extended by re-analyzing the set of knowledge artifacts for completeness. It is not uncommon for knowledge dependencies to be overlooked during the initial analysis and for additional knowledge artifacts to be identified as analysis continues. More specifically early analysis tends to focus on explicit knowledge artifacts and it can be helpful in later stages to deliberately focus the analysis on implicit and tacit knowledge artifacts.

7. Field Experience

To date the KFAM approach to knowledge flow modeling and analysis has been successfully field tested and applied in both the private and public sectors. In the corporate environment, KFAM has been used to support resolution of problems in project management, financial planning, process design, and enterprise architecture development. Within the public sector it has been applied and tested through the study of the public education finance in Delaware [3], [4] and in the design of a knowledge engineering function to support enterprise architecture management for an executive department within the federal government.

In the Delaware study, using no more than basic hand-drawn models and with little if any familiarity with knowledge flow modeling financial business managers for school districts in Delaware sketched basic KFAM models showing how a leader knows the district is entitled to hire a state-funded teacher. Creating this model quickly allowed the participants to see that the hiring decision, which had previous been seen as a single activity, was actually comprised of four sub activities [2]

At a network equipment vendor KFAM was used to identify workflow problems in the conversion of technical manuals involving both a documentation group (responsible for the converting the content) and a technology group (responsible for the developing the systems that were to be populated with the converted content). After considerable organizational conflict that threatened high-visibility deadlines, this approach was successfully used to identify the fact that critical knowledge required to enable activities assigned to the documentation group was in-fact held by the technologists. Based on these findings, responsibility assignments were refined, resolving the problem.

At a major technology vendor, KFAM was used to design new processes. Even though the client had no prior knowledge management experience, the key terms and concepts were readily understood. The explicitness of the models ensured that key issues were quickly identified, diagnosed, and resolved. The resulting processes were turned over to other personnel and executed without incident.

In work supporting the Office of Information and Technology (OI&T) within a department of the executive branch of the federal government, the GKM was used as the unifying conceptual framework to design a new line of business intended to provide knowledge management services that were scalable at an enterprise level. These designs included a knowledge engineering capability centered on the use and application of KFAM. As part of a FSAM-compliant architecture (Federal Segment Architecture Methodology) [14], KFAM models were also used to document the To-Be architecture of this new line of business. Through not yet formally adopted, the pilot implementations have already been used to target problem areas: knowledge loss due to attrition and the development of submission packages for the Congressional budgeting process.

8. Conclusions and Future Work

The experience gained by the authors and others has shown the KFAM approach to be a viable way to develop shared understanding between themselves, business managers, and knowledge engineers.

Specifically; we have found the KFAM approach:

- Is useable and provides value with minimal initial training, and to provide repeatable results in the form of knowledge flow models that that clarify the relationships between business processes and acquisition, retention, transfer, and use of knowledge to enable the actions and decisions within those processes.
- Supports the identification of knowledge flows and the actions and decisions they enable. Allows the mapping of business process activities to knowledge utilization events, the identification of knowledge flow behaviors and the analysis of the roles agents play as a path for enabling knowledge.
- Is scalable both in the level of detail required at any given point and the ability to represent knowledge flows from the individual process through the enterprise level.

8.1 Lessons Learned

Based on experience applying these methods in a range of academic, business, and government settings, and from feedback received by a number of early adaptors, the authors have continued to refine and expand these knowledge flow modeling and analysis techniques. While captured due to their specific relevance to the KFAM approach, the three lessons we have chosen to highlight would appear to be relevant to knowledge flow modeling and analysis efforts irrespective of the methods used.

The first and most global of these is that the goals driving the analysis and modeling activity should be clearly identified and supported with well-articulated and actionable strategies for realizing those goals. Of near equal importance and applicability is that care needs to be taken to ensure that the initiative has the requisite business process knowledge in order to avoiding wasting time and resources during codification and interpretation activities.

Perhaps more directly related to the KFAM approach is that sufficiency and/or consistency problems in knowledge flows are often caused by activities that are not supported by all necessary enabling knowledge. Such problems include decisions that are not supported by requisite criteria and knowledge creation activities that are not supported by sufficient understanding how the knowledge is to be used. In one case, the preferences of the individuals constructing knowledge flow models drove a variety of representation styles. Attempts to share and integrate these models suffered from a general problem that occurs when codification and abstraction characteristics differ across one or more of the artifacts used to enable or constrain a given action. Once this issue was understood, the lesson was used to improve the KFAM syntax. Interestingly, this lesson came as a result of a double loop learning exercise in which KFAM analysis was used as part of a post-action review of a knowledge flow modeling session using KFAM.

8.2 Future Work

Experience gained through the use of KFAM has highlighted a number of areas for further development.

One need is for better methods for understanding the economic and temporal dynamics within knowledge flows, such as those associated with co-location of knowledge sources and point of use (e.g., decision making authority).

Further work is also needed in the area of agent analysis, involving the match between available KSAs and the knowledge requirements for a given activity. These enhancements would be expected to improve such functions as Human Resource management and Knowledge Asset management. They should also be applicable in the area of knowledge flow risk analysis, enabling better identification of perceived risk and risk acceptance thresholds.

Drawing upon observations of current practice in the area of systems dynamics [1], a growing use of KFAM methods and techniques over a broader range of settings could be expected to drive developments in the identification and application of knowledge flow archetypes. Ideally, these archetypes would be used with automated pattern recognition systems to identify problems in agent to artifact relationships, diagnose issues with knowledge artifact codification and interpretation, and assess the quality of enabling and constraining knowledge flows into a given KU in terms of their sufficiency and/or consistency.

KFAM, as described in this paper, was developed in response to needs experienced by the authors rather than through structured design. Many of the conditions that informed the development were client or situation-dependent. For that reason, it would not be practical to attempt to test the repeatability of design process under controlled conditions. With the exception of the work performed by Carter [2], these same limitations would apply when attempting to replicate the antidotal evidence used to support the claims of usability, coverage, and scalability. Given the availability of suitable study environments, the authors plan to continue their research in this area including more extensive and formal testing and evaluation.

9. References

[1] Bellinger, G. (1996-2002). Personal Communications.

[2] Carter, A. L. (2009). A Study of Knowledge Flow: A Delineation of Public Education Finance in Delaware. Dissertation. Wilmington University.

[3] Carter, A. L. (2010). Applying KM Techniques in the Development of an Executive Position Paper on Public Education: Closing the Gap Between Theory and Practice. unpublished.

[4] Collins, S. T. (2009). Wading and Jumping into a New Job-Exploring Dynamics of Knowledge Flow for Systems Engineers. Human Organization, Society for Applied Anthropology , 68 (2), 194-205.

[5] Conrad, K. W., Beck, B. D., & Smith, B. (2006). Values: The Ultimate Semantic Technology. Semantic Technology Conference. San Jose.

[6] Day, R. E. (2005). Clearing up 'implicit knowledge': Implications for Knowledge Management, Information Science, Pyschology, and Social Epistemology: Research Articles. Journal of the American Society for Information Science and Technology , 56 (6), 630-635.

[7] Dienes, Z., & Perner, J. (1999). A Theory of Implicit. Behavioral and Brain Sciences , 22, 735-808.

[8] Ellis, C. (1979). Information Control Nets: a Mathematical Model of Office Information Flow. Simulation, Measurement and Modeling of Computer Systems.

[9] Ellis, C. A., & Nutt, G. J. (1993). Modeling and Enactment of Workflow Systems. International Conference on Application and Theory of Petri Nets.

[10] Forrester, J. W. (1975). Collected Papers of Jay W. Forrester. Waltham, MA: Pegasus Communications.

[11] Forrester, J. W. (1994). System Dynamics, Systems Thinking, and Soft OR. System Dynamics Review , 10, 245-256.

[12] Frappaolo, C. (2008). Implicit Knowledge. Knowledge Management Research & Practice , 6, 23-25.

[13] Goodman, M. R. (1997). Study Notes in System Dynamics. Journal of hte Operational Research Society , 48 (1147), 1147.

[14] Griffiths, D. (2009). Knowledge Management: Toward Overcoming Dissatisfaction in the Field. World of Academy of Science Engineering and Technology , 724-735.

[15] Holt, P. A. (2000). Management-Oriented Models of Behavior Processes. In Lecture Notes in Computer Science. Berlin/Heidelberg: Springer.

[16] Karnopp, D. C., Margolis, D. L., & Rosenberg, R. C. (1990). System Dynamics: a Unified Approach (2nd ed.). New York: Wiley.

[17] Lohmann, N., Verbeek, E., and Dijkman, R. 2009. Petri Net Transformations for Business Processes --- A Survey. In Transactions on Petri Nets and Other Models of Concurrency Ii: Special Issue on Concurrency in Process-Aware information Systems, K. Jensen and W. M. Aalst, Eds. Lecture Notes In Computer Science, vol. 5460. Springer-Verlag, Berlin, Heidelberg, 46-63.

[18] Merz, M. D., Moldt, D., Muller, K., & Lamersdorf, W. (1995). Workflow Modeling and Execution with Coloured Petri Nets in COSM. University of Hamburg Department of Computer Science.

[19] Mooradiian, N. (2005). Tacit Knowledge: Philosophic Roots and Role in KM. Journal of Knowledge Management , 9 (6), 104-113.

[20] Naeve, A. (2005). The Human Semantic Web - Shifting From Knowledge Push to Knowledge Pull. International Journal of hte Semantic Web and Information Systems , 1 (3), 1-30.

[21] Newman, B. D. (2003). Agents, Artifacts, and Transformations: The Foundation of Knowlege Flows. In C. Holsapple (Ed.), The Knowledge Mangement Handbook. Berlin: Springer-Verlag.

[22] Newman, B. D., & Conrad, K. W. (1999, Spring). Knowledge Mangement Characterization Framework. used in The Introduction to Knowledge Mangement Course EMGT 298 . George Washington University.

[23] Newman, B. D., & Conrad, K. W. (2000). A Framework for Characterizing Knowledge Management Methods, Practices, and Technologies. Third International Conference on Practical Aspects of Knowledge Management (PAKM2000). Basel, Switzerland.

[24] Nissen, M. E. (2002). An Extended Model of Knowledge-Flow Dynamics. Communications of the Association for Information Systems , 8, Article 18.

[25] Nissen, M. E. (winter 2005-06). Dynamic Knowledge Patterns to Inform Design: a Field Study of Knowledge Stocks and Flows, in an Extreme Organization. Journal of Management Information Systems , 22 (3), 225-263.

[26] Nissen, M. E., Kamel, M. N., & Sengupta, K. C. (2000). Integrated Analysis and Design of Knowledge Systems and Processes. Information Resources Management Journal , 13 (1), 24-43.

[27] Nonaka, I., & Takeuchi, H. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamcis of Innovation. New York: Oxford University Press.

[28] Harmon, P. (2007). Business Process Change: 2nd Ed, A Guide for Business Managers and BPM and Six Sigma Professionals. Morgan Kaufmann

[29] Polanyi, M. (1967). The Tacit Dimension. New York: Anchor Books.

[30] Polanyi, M. (1969). Knowing and Being. (M. Grene, Ed.) Chicago: University of Chicago Press.

[31] Reijers, H. A., Limam, S., and Van Der Aalst, W. M. 2003. Product-Based Workflow Design. J. Manage. Inf. Syst. 20, 1 (Jul. 2003), 229-262.

[32] Schacter, D. L. (1987). Implicit Memory: History and Current Status. Journal of Experimental Psychology: Learning, Memory, and Cognition , 13, 501-518.

[33] Sorenson, O., Rivkin, J., & Fleming, F. (2004). Complexity, Networks and Knowledge Flow. Academy of Management.

[34] Speigler, I. (2000). Knowledge Management: a New Idea or a Recycled Concept. Communications of the Association for Information Systems , 3, 1-24.

[35] US Office of Management and Budget. (2008, December). Federal Segment Architecture Methodology (FSAM) v 1.0. US Office of Mangement and Budget: Architecture and Infrastructure Committee (AIC).

[36] Van de Aalst, W. e. (2003). Business Process Management: A Survey. In Lecture Notes in Computer Science. Berlin/Heidelberg: Springer.

[37] Van der Aalst, W., & Van Hee, K. M. (2009). Workflow Model Analysis. In Encyclopedia of Database Systems. Springer.

[38] Yoo, K., Suh, E., & Kim, K. (2007). Knowledge Flow-Based Business Process Redesign, Appying a Knowledge Map to Redesign a Business process. Journal of Knowledge Mangement , 11 (3), 104.

[39] Zisman, M. D. (1977). Representation, Specification and Automation of Office Procedures. PhD Thesis . University of Pennsylvania.