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Organizational Knowledge Maturity and Complementarity: A Conceptual Framework

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Abstract

Knowledge has become a primary organizational resource and many organizations have focused attention on Knowledge Management (KM) as a means of enhancing their performance. KM encompasses a range of activities including the creation and capture of knowledge, the transfer or sharing of this knowledge and its application and reuse in organizations. KM has also been defined as providing the strategy, process and technology to shape and leverage expertise and knowledge across an organization so as to enhance the effectiveness of decision-making and thereby lead to improved performance. We have constructed a Knowledge Management Integrative framework to represent a range of activities associated with knowledge assets and their management. We seek to apply complementarity theory and a business value modeling approach to this framework to explore the benefits that can be accrued by an organization.

Complementarities exist when the incremental benefit from leveraging two variables is greater than the sum of the incremental benefits from leveraging each in isolation. By combining this theory with a multi-stage business value model, we argue that organizational benefits from investments in KM initiatives can be maximized when knowledge assets are leveraged in a concerted manner.

Keywords: Knowledge management, knowledge maturity, complementarity, supermodularity, submodularity and knowledge sharing

Introduction

The importance of Knowledge Management (KM) is succinctly provided in an article titled "If Only We Knew What We Know" (O'Dell and Grayson 1998). It is essential that every organization should start with an assessment of its current KM capabilities. KM, as a discipline, is designed to provide strategy, process, and technology to increase organizational learning (Satyadas et al. 2001). KM and KM Systems have been defined as new applications based on the existing IT infrastructure (King, et al. 2002). These applications have ranged from traditional data-processing areas, such as knowledge enabled supply chain management (SCM) systems, to expert networks designed to facilitate expert-to-expert communication. The various system designs attempt to capture and capitalize on the existing explicit, implicit and, in some cases, tacit knowledge of organizations. Implicit knowledge is expert knowledge that can be documented and made explicit, whereas tacit knowledge can be transferred only through observation. While the capture of tacit and implicit knowledge can be problematic, organizational learning, or use of captured knowledge, can be inhibited by knowledge barriers created by diverse complex technologies (Fichman and Kemerer 1997). Organizations must develop an integrative approach to KM that covers all potential components of knowledge and leverages current knowledge to reduce knowledge barriers and enhance organizational learning. In addressing these issues of KM, we believe that an organization must first discover "what we know". This discovery should not be restrictive in the sense of targeting single organizational areas or single systems for improvement, but must encompass the entire organization and map each area of strength and weakness. We develop an integrative framework by identifying knowledge areas that encompass all aspects of an organization's efforts to capture, store, retrieve, and use its knowledge assets, using two different research streams as outlined below.

Te identification of relevant knowledge areas is achieved through reviews of the existing body of KM research. King et al. (2002) identified the four KM application areas of knowledge repositories, lessons learned, expert networks and communities of practice. The Cognizant Enterprise Maturity Model - CEMM (Harigopal and Satyadas 2001) introduced the concept of measuring 15 Key Maturity Areas within an organization to improve business value. These recent efforts to identify and support business value from KM implementation highlights the need for extended organizational research within KM. Our second stream of research draws on the theory of Complementarity (Edgeworth 1881). Applying complementarity to knowledge areas, we attempt to identify significant decision variables that exhibit complementary relationships. The identification of these decision variables anticipates the result of obtaining supermodular benefits (Barua et al. 1996) from leveraging two or more decision variables in tandem. By identifying these complementary variables, organizations can more accurately judge the potential benefits accrued through investment in KM initiatives. Additionally, based on the relational strength of the decision variables, organizations can ascertain whether incremental or radical change is applicable.

In the following section, we introduce our framework in which five Knowledge Maturity Areas (KMA) are defined. Within each of these KMA's, we define decision variables (DV's) that can be used to measure the current level of effectiveness of each KMA. Next, we present our argument on complementarity and explore existing grounds that support complementarity both within KMA's and between KMA's. The identification of complementary relationships is used to provide support for achieving supermodular benefits when simultaneously leveraging two or more DV's. The final section discusses the implications of our theoretical framework. Additionally, an outline for empirically testing this framework is presented.

KM Integrative Framework

The framework presented here provides a way to assess the overall level of an organization's knowledge management initiatives, by identifying five KMA's. These five KMA's support organizational knowledge use (see Figure 1) and ultimately affect the profitability of the organization. The KMA's are **Lessons Learned**, **Knowledge Documents**, **Expertise**, **Policies & Procedures** and **Data**. An organization may be at a different level on each of these KMA's. To assess the existing maturity levels, we operationalize each KMA using a set of DV's. Note that, while the focus of our current research resides with the supermodular benefits that can be obtained from leveraging the DV's, we also recognize that there are costs associated with leveraging those DV's as outlined in the section on future research. The selection of these KMA's combats the tendency toward "silo" behavior noted as one of the barriers to the transfer of knowledge (O'Dell and Grayson 1998). These KMA's are designed to apply to organizational objects as a whole as well as the business units within an organization.

Knowledge Maturity Areas (KMA)

In describing each KMA and its place in the integrative framework, we ask the questions: 1) What strategy needs to be employed to use this KMA as a knowledge resource? 2) What processes are required to operationalize the strategy? 3) What technologies are needed to enable these processes?

Lessons Learned is the useful knowledge gained while completing a project or a task. Lessons learned are unique aspects of knowledge in that they are singular and specific to situations. The key strategy for Lessons Learned is to promote learning from past successes and failures. This strategy also promotes the use of best-known methods. The process includes the capture, storage and retrieval of Lessons Learned. Enabling technologies must utilize a taxonomy such that, once a lesson has been learned, it can be documented, applied and reused. The most difficult aspect of Lessons Learned is recognizing that a lesson has been learned.

In contrast to Lessons Learned, **Knowledge Documents** have a broader focus and can originate either internally or externally. Text based forms of knowledge documents can include: project reports, technical reports, research reports and publications. Alternative forms include: pictures, drawings, diagrams, presentations, audio and video clips, on-line manuals, tutorials, etc. In this sense, knowledge documents may not be "documents" per se, but can represent "documented knowledge" of diverse types. The strategy is to achieve easy identification of relevant sources of knowledge that enhance learning. The process for using Knowledge Documents includes cataloging, storage and retrieval methods. Enabling technologies provide intuitive taxonomies, nimble indexing and encompassing search methods. Knowledge documents should be obtainable both in summary and their complete original form.

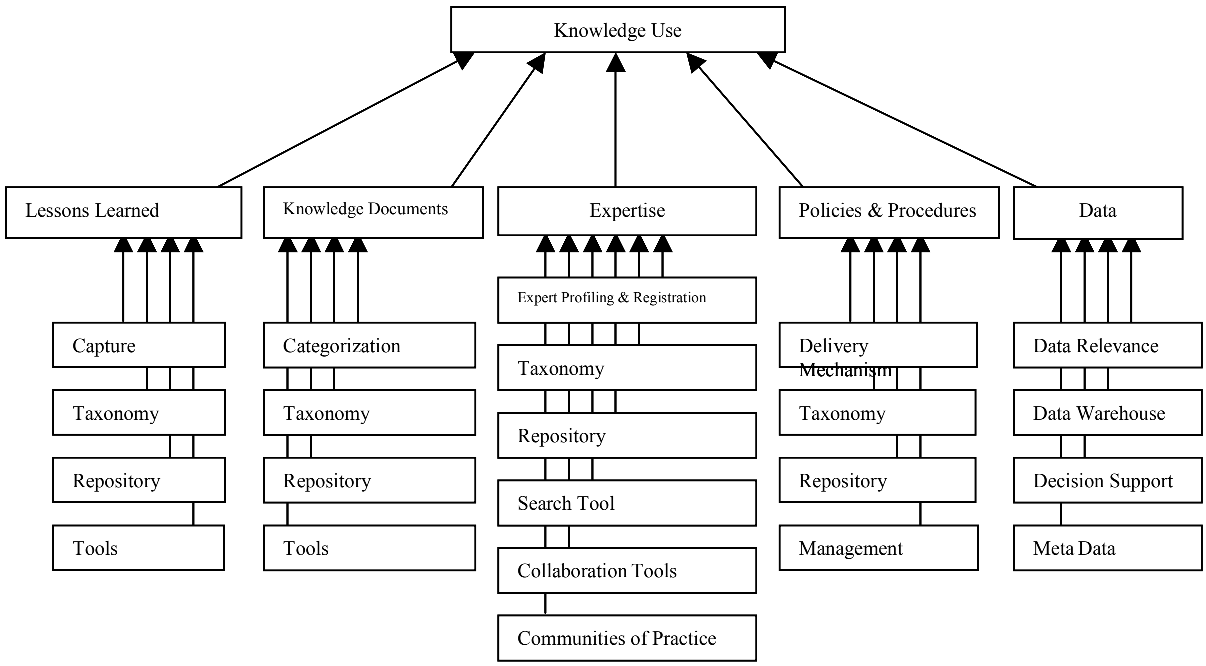

Figure 1. Knowledge Maturity Area Model

Expertise is knowledge that may be gained through experience or formal education. This knowledge is not easily captured but can be transferred through observation or mentoring. The strategy is to retain Expertise and promote its utilization, thereby maintaining and enhancing the core and related competencies of the organization. The processes necessary include: identification of experts in core and related areas, registration of their expertise, making contact with experts, and sharing of expertise through one-on-one and group collaborations. The technologies that can facilitate these processes include a well-developed expertise taxonomy and collaboration systems.

The three KMA's described above – Lessons Learned, Knowledge Documents, and Expertise — are commonly accepted areas of knowledge and are often cited in the current research literature on knowledge management. We recognize that Knowledge assets are fairly diverse and that these three areas may not cover all aspects of knowledge management. We therefore introduce two additional areas — **Policies & Procedures** and **Data —** to complement the three.

Policies & Procedures represent institutional knowledge required for efficient and consistent operation of an organization. Policies & procedures document the workflows for routine operations. The clarity and consistency of policies & procedures can assist in the assimilation of new personnel. The strategy is to promote clear and concise articulation of functional knowledge for the appropriate audience. The process includes timely delivery of relevant Policies & Procedures to accomplish routine organizational tasks. The enabling technology used must focus not only on user initiated retrieval of Policies & Procedures documents, but also on the automated delivery of relevant knowledge in the context of their needs.

The conflict of whether data is knowledge or knowledge is data has been debated much the same way as the chicken and the egg. A common view holds that data is raw numbers, information is processed data and knowledge is authenticated information (Alavi and Leidner 2001). The dichotomous view reverses the data to knowledge assumption and states that knowledge must exist before information can be formulated and before data can be measured to form information (Tuomi 1999). However, there is no disagreement about transaction processing systems containing actionable information for making knowledgeable decisions that impact organizational direction. **Data**, as a KMA, may therefore provide many complementary benefits to the leveraging of other KMA's. It's inclusion as a KMA is justified theoretically, as initially stated, and practically, due to the face validity of its actionable information.

From a practical standpoint, data includes the facts or figures obtained from operations, experiments, surveys, etc. The data resides in databases and/or data warehouses. The strategic use of data is in the promotion of data-driven decision-making. The organizational process includes identification, collection, and maintenance of actionable data. Transaction processing systems and data warehouses are examples of the enabling technologies to be employed.

Decision Variables

When identifying decision variables within each KMA, we applied the criteria of unique contribution to the KMA as well as possessing an identifiable discrete or continuous scale anchored by ideal vs. base conditions. The decision variables under each KMA are as follows:

1) Lessons Learned (Capture, Taxonomy, Repository, Tools)
2) Knowledge Documents (Categorization, Taxonomy, Repository, Tools)
3) Expertise (Expert Profiling & Registration, Taxonomy, Repository, Search Tool, Collaboration Tools, Communities of Practice)
4) Policies & Procedures (Delivery, Taxonomy, Repository, Management)
5) Data (Data Relevance, Data Warehouse, Decision Support, Metadata)

Lessons Learned

A primary tenet of **Capture** is that as soon as a lesson is learned, it should be documented. Lessons Learned can be fleeting in nature, in that they can be temporarily in a person's mind when the learning occurs or they may be implicit within project or task reports. Thus at the lowest level of maturity of this DV, Lessons Learned may not be captured; they may only be transmitted by word of mouth. Their systematic capture requires that they be an essential part of the workflow process. Hence, at high levels of maturity, Capture may include the identification of Lessons Learned during formal debriefings of projects.

The **Taxonomy** of Lessons Learned is the classification scheme that is used while capturing the Lessons Learned as well as during their storage and retrieval. Aspects of taxonomy should specify project or task type, provide scaled dimensions and identify relationships between Lessons Learned on similar projects. At the most basic level, Taxonomy may be fairly ad hoc and may not facilitate efficient storage and retrieval. At an improved level, Taxonomy should be well understood by knowledge workers, be relatively static in nature, and provide a degree of flexibility and adaptability in order to facilitate evolution.

Repository is the storage design for Lessons Learned. Lessons Learned are mostly internal to the organization. Due to this internal nature, Lessons Learned are finite in scope and the repository can be highly structured. At low levels of maturity, Repository may be non-existent, comprised of physical documents in file cabinets, or electronically stored in personal file folders. At high levels, Repository can support Taxonomy of Lessons Learned, as well as allow multiple access paths for efficient retrievals.

Tools utilize the Taxonomy to aid in the addition, search and retrieval of Lessons Learned from the repository. The quality of Tools is determined by their utility, ease of use, intuitiveness of their user interface, and their extent of customization/ personalization. Basic Tools may provide guidance in finding relevant Lessons Learned, but may be difficult to use and/or inadequate from the viewpoint of the knowledge workers. At the high end, Tools may exhibit intelligence, i.e., use context and personalization in categorizing as well as retrieving Lessons Learned.

Knowledge Documents

Categorization starts with identification of Knowledge Documents. After that, the documents need to be catalogued for later use. Due to the diverse nature of Knowledge Documents, Categorization must include multiple methods to ensure that text-based reports as well as non-text based knowledge sources are identified and catalogued. The basic level of Categorization may facilitate text-based documents only. Full implementation may include recognizing various sources of documented knowledge and cataloguing them according to pre-defined classification schemes.

The **Taxonomy, Repository** and **Tools** of Knowledge Documents contain unique differences in application as compared to Lessons Learned. Taxonomy is unique due to the variability of Knowledge Documents. This variance necessitates a more loosely structured Taxonomy. The Repository for Knowledge Documents consists of a centralized catalog that supports a collection of documents distributed over the corporate and external networks. The Tools must be able to incorporate the variations in knowledge documents efficiently. Search and retrieval of these documents must seamlessly encompass both internal and external sources. The progressive levels for each of these DV's are similar to those for Lessons Learned.

Expertise

Expert Profiling & Registration measures how thoroughly experts within an organization are identified as knowledge sources. The simplest form is a word of mouth scheme. At the highest level, forms of auto profiling may exist which include: experts answering profiling questions, scanning of scheduled activities (like training) to automatically update the index and inclusion of external expertise.

Taxonomy, Repository and **Search Tools** of Expertise also contain unique differences in application as compared to Lessons Learned and Knowledge Documents. Taxonomy must include the identification of certifications, education level, history of problems solved and technical expertise. Repository is predominantly internal, but should have provisions for expert identification outside the organization. Search Tools should provide easy response to locating the appropriate expertise.

Collaboration Tools are indicative of expert-to-expert interaction and include: 1) face to face, 2) phone conversations, 3) teleconferencing and 4) electronic network enabled synchronous/asynchronous interaction. Synchronous interaction is typified by instantaneous feedback and a high degree of mutual collaboration. Asynchronous interaction highlights a timed feedback in which one expert reviews an item, provides comments and then sends those comments on to the next expert (or initiator of the problem).

Communities of Practice encourage the use of Special Interest Groups (SIG's) and Communities Of Experts (COE's) to insure that organizational core competencies are strengthened. These informal social organizations emphasize the improvement of Expertise both for the experts and for those individuals attempting to acquire greater knowledge. The level of use and utilization of both internal and external SIG's and COE's provides an organizational measure of the continued honing of skills for Expertise.

Policies & Procedures

Unlike Knowledge Documents or Expertise, which are sought by users, individuals do not routinely search for organizational Policies & Procedures. Thus, to disseminate Policies & Procedures, a **Delivery** mechanism must be developed and implemented to make this knowledge not only available, but also pushed to the intended audience. At a base level, Delivery may be accomplished through an "Employee Handbook" received upon hiring. A high maturity level may require a more efficient implementation that provides timely Delivery of Policies & Procedures to committees or workgroups at the point of need.

Taxonomy and **Repository** are the Classification Scheme and the design of storage for Policies & Procedures. Since it contains institutional knowledge, Repository resides internally and allows a highly structured Taxonomy. The progressive improvement levels are similar to those for Lessons Learned.

Management encompasses the scope and efficiency of Policies & Procedures. Scope is concerned with the organizational areas requiring or needing consistency of operation. Efficiency identifies whether Policies & Procedures in place are inflexible or allow some flexibility. Rigidity of policies and procedures inhibits autonomous behavior. The existence of knowledge captured in a few policies and procedures is the base level of Management. To achieve higher levels, the scope and efficiency of Policies & Procedures must actively be managed. Ideal Management is achieved when an organization has all the pertinent policies and procedures in place, ready for use by members of newly formed committees or reassigned positions (i.e.: project team, department head search committee, lateral department moves, etc.), while allowing autonomy to override these when required.

Data

Data Relevance criteria are defined by the varying knowledge worker requirements. Data Relevance can contain the multiple criteria of currency, granularity, timeliness and accuracy. Data currency is a measure of how "up to the minute" is the required data. Data granularity refers to a user's need to move from a macro to micro data view. Data timeliness measures the time from request to receipt of data. Data accuracy measures the "correctness" of the data. At the base level, data may have no use in facilitating decisions within an organization. Ideally, a decision-maker will be able to obtain data instantaneously, with complete accuracy and having the correct measurement metric.

Data Warehouse contains the data necessary to facilitate managerial decision-making. The processes needing support dictate the types of data required from the data warehouse, which may vary based on the business units' needs. At the base level, an organization has no Data Warehouse. Once a data warehouse is implemented, the ideal measure is based on the needs of the knowledge worker. Ultimately, multiple levels of organizational decision-making must be fully supported by Data Warehouse.

Decision Support includes models, tools and data presentation capabilities. Decision support models can range in complexity from the mind of the user to an implemented Decision Support System (DSS). The existence of a DSS model signifies the existence of a strategic decision to utilize data in a coordinated effort. At the base level of Decision Support, a knowledge worker may have to manually collect relevant data, perform analysis and rely on individual judgment. At a high level, the knowledge worker has sophisticated analysis tools, which automatically use the relevant data.

Metadata is concerned with the description of data. High quality metadata allows a knowledge worker to ascertain what types of decisions can be supported using the available data. Tracking changes in the metadata provides statistical information about the data warehouse. At the base level, Metadata may not be descriptive enough to support DSS models. A mature organization may have Metadata that can be used for model building and application.

Complementarity Among KMA's

Next, we examine the linkages between the KMA's along with potential complementarity in the benefits that can accrue by jointly leveraging these KMA's. We start with an explanation of complementarity. Complementarity theory, introduced by Edgeworth (1888), was originally applied to market products that exhibited similar demand characteristics. The measure under study was the change in demand, over time, of two or more products (Δx &Δy). A positive Δx (demand for radio controlled cars) would have a complementary positive effect on Δy (demand for batteries). A company that supplies both x and y need only spend marketing capital to promote product x. The increased demand for x would result in a complementary effect on the demand for product y.

The application of complementarity theory to KMA's would imply a greater potential leveraging of knowledge assets given the identification of complementary factors. In the context of our proposed KM framework, complementarity theory would focus resources on improving those DV's that would jointly provide a greater benefit from knowledge assets. In theory, coordinated changes of complementary factors in tandem can have a greater impact on benefit than larger isolated changes. This concept is termed supermodularity.

Supermodularity (and submodularity) (Topkis 1978) involves general functions defined on lattice spaces and incorporates complementarity within sub-lattices to indicate and identify feasible organizational choices. The concept of supermodularity targets the benefits accrued when leveraging multiple complementary factors that impact benefits. On the other hand, submodularity targets the costs incurred in leveraging multiple complementary factors. In the following discussion, we focus on supermodularity of benefits. Barua, et al. (1996) applied the concept of supermodularity and submodularity to improving the success rate of Business Process Reengineering (BPR). Their work discussed the impact of coordinated changes in organizational processes and the magnitude of such changes.

Consider the expected knowledge benefits arising from isolated and coordinated changes to two DV's in the Expertise maturity area: e => (Expert Profiling & Registration) and f => (Taxonomy). We define the following levels of these two DV's and provide a formal definition of supermodularity.

$e_1 \geq$ basic maintenance of resume
$e_2 \geq$ standard structured format for registering expertise
$f_1 \geq$ coarse Taxonomy
$f_2 \geq$ fine Taxonomy

where $e_2 > e_1$ and $f_2 > f_1$

Let Δe represent the improvement from e_1 to e_2, while Δf represents the improvement from f_1 to f_2.

$K(\Delta e, \Delta f)$	Incremental benefit of leveraging e and f in tandem (coordinated changes)
$K(\Delta e)$	Incremental benefit of improvement in e alone

$K(\Delta f)$ Incremental benefit of improvement in f alone

Supermodularity exists when the incremental benefit of a coordinated change exceeds the sum of the benefits of isolated changes.

$$K(\Delta e, \Delta f) \geq K(\Delta e) + K(\Delta f)$$

The following examples illustrate how complementarity can exist between DV's both within a KMA and between KMA's.

Complementarity Within KMA's

Contemplating an improvement in expert participation for knowledge sharing, (see Figure 2), an organization may wish to provide improved Collaboration Tools. With Collaboration Tools that include only phone/email, the level of interaction between experts may be limited. By providing groupware, (i.e. improved Collaboration Tools) the interaction between the experts in the community can be enriched. Richer interaction leads to better knowledge sharing, utilization and organizational learning. At the same time, merely providing better Collaboration Tools may not yield significant benefits without established Communities of Practice to utilize those tools. This also illustrates the need to match the levels between the two DV's. Local groups may only need access to phones, whereas, geographically dispersed groups may need more sophisticated Collaboration Tools. Hence a concerted effort toward building Communities of Practice can yield supermodular benefits.

Consider a firm that would like to improve the way lessons learned are captured upon completion of a project or task (see Figure 3). The improvement is expected to proceed from hard copy documentation to electronic documentation. In addition, by providing a centralized electronic repository, which is highly accessible to prospective users of lessons learned, the potential for utilization of this knowledge can be substantially increased. If both Capture and Repository are improved in tandem, (Capture – through electronic documentation and access to Repository – through centralization), overall organizational knowledge benefits are expected to be supermodular.

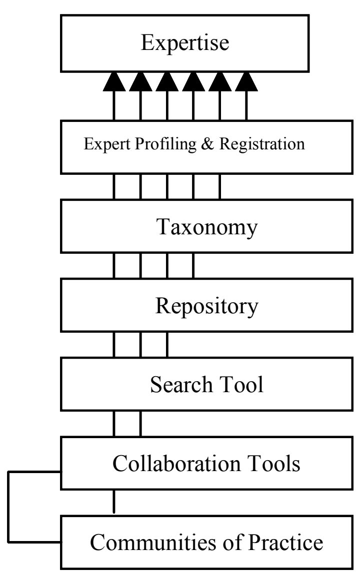

Figure 2. E Complementarity

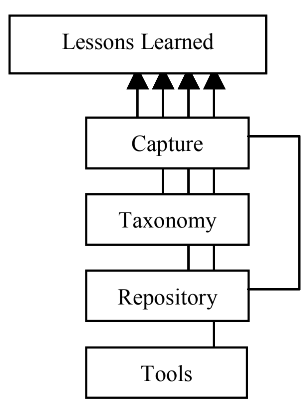

Figure 3. LL Complementarity

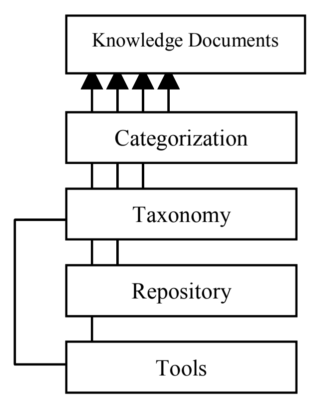

Figure 4. KD Complementarity

Another example of supermodularity stems from a natural complementarity between Taxonomy and intelligent search Tools in the context of Knowledge Documents KMA. Assuming that the existing taxonomy does not adequately discriminate between the various forms of knowledge documents (see Figure 4), improvement to a more versatile taxonomy is contemplated to utilize varying functional and specific subject areas of knowledge documents. While search tools can take advantage of a multi-dimensional taxonomy, a search tool with added intelligence that utilizes context and personalization of the user can potentially achieve exponential improvement through refinement of search results.

Complementarity Between KMA's

As an example of complementarity between Lessons Learned and Policies & Procedures (see Figure 5), consider the situation where an ad hoc committee is assembled to locate a new department chair. For the committee to function, knowledge about the required policies and procedures to execute the search is essential. Given the charge of the committee, if applicable policies and procedures can be automatically delivered to the committee immediately upon its formation, the planning of the hiring process will be improved. In addition, accessibility to prior lessons learned concerning for example, outlets for making the search announcement, interview questions, and candidate evaluation process would be valuable to the committee. If both these mechanisms – delivery of relevant policies and procedures and access tools for relevant lessons learned – are in place, a significantly greater improvement may be realized in the hiring process.

Complementarity between Data and Lessons Learned (see Figure 6) is illustrated by the following example. Consider an organization trying to move from a lower to a more sophisticated level of Decision Support so that more effective decisions can be made. If the user has access to the lessons learned in prior implementations of similar decisions, then the results of the DSS can be combined with the knowledge about prior successes and failures in similar situations. Assuming that the lessons learned (relevant to the present decision) have been captured, this higher level of Capture may significantly improve the quality of the decision process, suggesting supermodularity.

While Taxonomy of Expertise and Taxonomy of Knowledge Documents have different foci, construction and improvement of these taxonomies simultaneously can exhibit complementarity (see Figure 7). A well-designed Taxonomy of Knowledge Documents can improve the availability of relevant knowledge documents in an area of interest. A similar Taxonomy of Expertise can identify an expert in the area. A quick inquiry to the expert can allow better interpretation of knowledge documents resulting in greater gains in knowledge worker productivity. Another way of looking at this complementarity is that knowledge documents can help knowledge workers educate themselves about the subject matter so that they are better able to orient themselves to the opinion of the expert in the context of the problem they are trying to solve.

Discussion and Implications

Industry Application

We have presented a theoretical framework utilizing the concept of Complementarity to the identification and measurement of Knowledge Maturity Areas that can be applied to organizations. In today's knowledge-based economy, greater emphasis is being placed on managing organizational knowledge assets. The full potential of corporate knowledge assets and the effective management of those assets still remains an under researched area. By identifying where an organization is positioned with reference to each DV in each KMA, an overall score can be constructed for the organization's knowledge maturity. The application of Complementarity can guide organizations in targeting the KMA's, or specific DV's, where the most benefits can be achieved for the effort and resources expended.

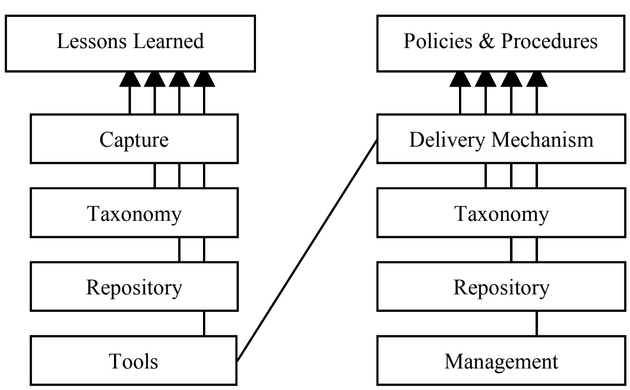

Figure 5. Complementarity Between LL & P&P

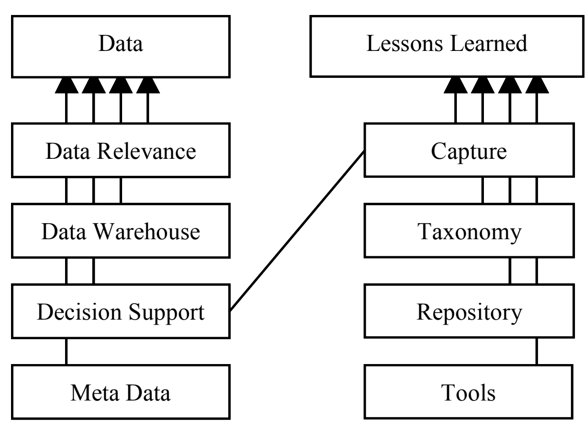

Figure 6. Complementarity Between Data & LL

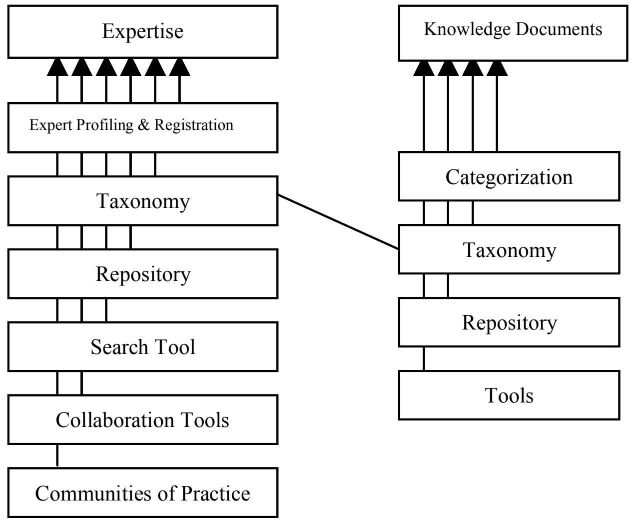

Figure 7. Complementarity Between Expertise & KD

Future Research

We propose continuing our line of research in three directions that extend the application of complementarity within knowledge maturity areas and their decision variables. The first is the empirical measurement of organizational levels on DV's and the strength of the links of each KMA to organizational performance. The development of a survey instrument to measure each KMA and the overall "quality" of knowledge sharing and reuse is currently in progress. This will provide the means to identify performance linkages and complementarity between KMA's. Secondly, identification of costs associated with leveraging each DV and the examination of possible submodularity of costs needs to be investigated. Submodularity is the inverse of supermodularity. Submodularity implies that the cost of combined effort in respect of two DV's is less than the sum of the cost of isolated efforts. Thirdly, organizations also have potential pre-existing conditions that may facilitate or inhibit the management and leveraging of knowledge assets. These pre-existing conditions include cultural factors such as: motivation and reward mechanisms within the organization, propensity to undergo training and instruction for new initiatives, etc. While these cultural conditions may or may not be explicitly measurable, research is needed to identify their underlying impact on organizational knowledge sharing and use. For instance, if the organization is at a level where motivation of knowledge workers to participate in KMA improvement is not very pronounced, the improvement efforts may not yield dividends as high as expected. This may lead to insights on whether incremental change or radical change is desirable.

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