AN ECOLOGICAL MODEL FOR ORGANIZATIONAL KNOWLEDGE MANAGEMENT

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ABSTRACT

Research in Knowledge Management (KM) has gained distinguished attention in recent years, and different views of methods have been proposed in existing literature. An initial study was the process view that focused on the creation, organization, sharing, and application of explicit and tacit knowledge. Another recent perspective is the resource-based view that emphasizes how knowledge resources can develop organizational capabilities and enhance organizational performance. This paper builds on these past studies and presents an alternative view that examines the dynamic relationships between knowledge and organizational performance. This examination is based upon an ecological perspective that includes the distribution, interaction, competition, and evolution (DICE) among different biological species. From this ecological perspective, a model that consists of knowledge distribution, knowledge interaction, knowledge competition and knowledge evolution is proposed. These four elements interact with each other and evolve to maintain healthy knowledge ecology in an organization. A case study was conducted to support this innovative model. The major implication of the findings is that maintaining healthy knowledge ecology is important for the success of knowledge management in an organization.

Keywords: Knowledge management, knowledge ecology, the DICE model.

I. INTRODUCTION

As knowledge is becoming more and more important in today's economy, knowledge management (KM) is an important research area in Information Systems (IS). In the past decade, scholars from various disciplines including IS, Sociology, Economics, and Management have reported strong evidence that KM and related strategic movements are essential for organizations to survive and maintain their competitive advantages [2, 17, 56].

Research development in KM can be divided into two major stages. The first stage focuses on defining the scope of KM [26] and understanding the KM process, of knowledge creation and knowledge sharing, in organizations [33, 37, 49]. Nonaka [49], proposed a distinguished model in the knowledge creation cycle, which suggests that knowledge creation activities include socialization, externalization, combination, and internalization. From this research, an organization should focus on the process of knowledge creation, storage, retrieval, transfer, and applications. A review of this process view of KM can be found in Alavi and Leidner [1].

More recent research adopts a resource-based view that treats knowledge as organizational assets, to investigate effects on organizational capabilities and organizational performance [3, 36, 56]. These studies have found significant impact of KM activities on organizational creativity and organizational performance. Other research proposes to integrate different paradigms or empirically investigate knowledge-related behaviors in business applications. Hsieh et al. [30] explored the roles of KM in online procurement. Rowley [52] examined the relationship between KM and customer relationship management.

The process view of KM emphasizes knowledge-related human activities. However, it does not deal with the idiosyncratic nature of different types of knowledge or the relative importance of different knowledge in an organization. Although the knowledge cycle is generic to all knowledge types, the issue of maintaining the balance of different knowledge in an organization is as important as knowledge creation and knowledge sharing.

To use a sports analogy as an example, it is just like putting together a basketball team, a strong forward or center does not guarantee superior team performance. In many cases, the proper combination of players is as important as the power of the individual players. In addition to their individual capabilities, the chemistry among players will also have a significant impact on their performance. Along with this same philosophy of sport team management, it is important to maintain a portfolio of different knowledge in order to make an organization perform better. From this, KM in an organization should focus on building up the strength of a particular type of knowledge and on putting together a team with the right members who possess knowledge that can complement each other.

The purpose of this paper is to develop a new framework for studying organizational KM from an ecological perspective. The term *information ecology* is not new, it has been used in existing literatures [16, 46]. These literatures use ecology as a metaphor, but do not provide a framework for research. In this paper, we extend the ecological concepts to KM and develop specific propositions for further research. The remainder of the paper includes the following sections. Section II reviews the major literature in KM and ecological concepts. The DICE model is proposed based on this literature. The concept of knowledge ecology is discussed in Section III. Results from a case study and four propositions

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based on the DICE model are presented in section IV. Finally, implications and conclusions are discussed in Section V.

II. LITERATURE AND ECOLOGICAL CONCEPTS

1. Knowledge Management Frameworks

Research in KM can be traced to early work in the sociology of knowledge around 1970's [6, 26] and technical work in knowledge-based expert systems in the 1980's. In a review on KM and knowledge management systems (KMS), Alavi and Leidner [1] examined previous research from a process views. This research included activities such as creation, storage, retrieval, transfer, and application.

Another framework proposed by Grover and Davenport [25] stresses the exchange value of knowledge in a marketplace. KM was outlined as the problem of creating an effective and efficient knowledge marketplace in the organization. In their paper, they also illustrated key domains for pragmatic research on KM. It constructed relevant questions, such as strategy, structure, culture, and technology, which could facilitate knowledge process.

Schultze and Leidner [54] used the framework developed by Deetz [18] to classify KM research, between 1990 and 2001, into four scientific principles: the normative, the interpretative, the critical, and the dialogic. In the normative ideology, researchers were concerned with codification, the normalization of experience, and the search for authoritative relationships. The study reported that about 70% of the literature contained this paradigm.

In a recent work, Argote et al. [4] presented a KM framework, called "knowledge outcomes" that enhanced the traditional KM process by incorporating properties of knowledge context. In their study, KM outcomes include knowledge creation, knowledge retention, and knowledge transfer. KM context affects KM outcomes and can be organized according to whether they are properties of a unit, such as an individual group or organization. This is based upon properties of relationships between units or properties of the knowledge itself.

These diverse perspectives portray a rich picture of KM research. However, there are still important issues in KM that have not been investigated. From a top manager's point of view, a key concern would be whether KM should focus on a few key categories of knowledge or a broad scope of all kinds of knowledge under resource constraints? What kinds of knowledge configuration should be kept in the organization? What should the organization do to manage knowledge evolution to meet the dynamic change of the business environment? In this paper, we reiterate these questions from the ecological perspective.

2. Key Ecological Activities

Ecology is a science being used to analyze the relationship among members or species of a community and their interaction with the environment. Traditionally, ecology is defined as "the scientific study on the interactions that determine the distribution and abundance of organisms" [35]. Ecological study has been conducted at the species, the population, the community, and the ecosystem level. Species are the basic elements in ecology. A group of organisms of the same species occupying a particular space at a particular time form a population. Several populations gather together to become a community. The ecosystem includes the numbers of organisms, the mineral elements and the energy in which the complex and intrinsic interactions occur.

The purpose of ecology is to investigate the complex relationships between individuals and populations and between organisms and their environments. This area of interest has received tremendous attention in different fields of research that are derived from antiquity and are based on the sophisticated foundation of science [43]. In social science, ecological theories have received vast attention in the fields of evolutionary economics and organizational ecology [5, 11, 28, 48]. In organizational ecology, in the populations and communities of organizations, the ecology of organizations builds on the generalized ecological and evolutionary models of change. This ecological evolutionary approach is directly associated with organizational diversity, which is specific to the interrelated synergies between sources of increasing diversity and decreasing diversity [27, 28]. Ecological theories have introduced a creative view into organizational science, which has received significant attention.

Four concepts have been found to provide major functions in ecological research. They are ***D****istribution*, ***I****nteraction*, ***C****ompetition* and ***E****volution* of species and the acronym for this is designated the DICE model.

(1) Distribution

In essence, ecology studies the relationships among organisms in an environment. Therefore, the foundation of ecological research is the configuration of the biological system. One way to illustrate this configuration is to show the distribution of species or resources. In ecology, research related to the spatial distribution of species within their habitat is called "spatial modeling". This modeling system uses mathematical descriptions of an ecological system that accounts for the positions of the various populations as well as their quantities [19, 58]. The distribution of individuals in an environment will have a dramatic influence on their behavior, survival, reproductive success and it will influence the stability or dynamics in a community.

(2) Interaction

Once a community has diversity in population distribution, different species will have interactions within and outside the population [23]. From this interaction mechanism, information will spread among populations inside or outside the community. For example, populations residing near each other will create a higher frequency of interaction than populations residing further away from each other. This will create collaboration or competition depending on the strategy different populations adopt. In order for survival, each population will find a *niche* or a unique position for survival. The fundamental niche of a population consists of the set of all environmental conditions in which the population can grow or sustain its numbers [31].

(3) Competition

Populations in the same ecology may collaborate or compete. Those having niche overlap or sharing of the same niche will develop collaborative or competitive relationships during their interaction. Collaboration exists when species in a community find supplementary values. When resources are limited, competition is more natural, because each population has to fight against the other to sustain or develop itself [10, 11]. Here we use competition to include collaboration as a special strategy of competition, which reduces the tension of direct conflicts by sharing their resources.

(4) Evolution

During the process of interaction and competition, a process called evolution will occur. This is when the population gradually changes its inherited properties over generations to meet habitable conditions. The evolutionary pattern of a population is governed by the selection process that comes from activity in the environment. As a result, the evolutionary process is usually modeled as a selection process that maximizes the fitness or growth rate of a population. It should be noted that biological evolution refers to populations where changes must be passed on to the next generation [23, 48]. To state this in another manner, populations must adapt to their environment and from a longitudinal view, the evolutionary process is the result of competition.

III. THE KNOWLEDGE ECOLOGY MODEL

1. Knowledge Ecology Defined

With modification of the bio-ecological behavior described in Section II, a *knowledge ecology* model can be defined. The knowledge ecology of an organization is composed of four segments: knowledge, communities, organizational resources and external environment. Different types of knowledge are viewed as different *knowledge populations* and grouped into a *knowledge community* in the model. These knowledge communities build on top of *organizational resources* including staff, process, structure and culture. These maintain a balance with the *external environment* to maximize their interests through the four ecological mechanisms: distribution, interaction, competition, and evolution. Figure 1, illustrates their relationships.

Since a knowledge community is composed of many different types of knowledge populations, the DICE cycle is able to interpret their interaction and co-evolution behaviors. Knowledge distribution portrays the "what is" and the "how does" of many different knowledge populations existing in an organization. All of which may have different strengths or knowledge intensity. These knowledge populations will interact with internal or external populations to solve problems. When organizational resources are limited, these populations will need to compete, either collaboratively or in conflict, in order to get the job done. This will result in the populations evolving over time.

The basic unit for analysis in the ecological framework is the knowledge population, which is a subset of the whole knowledge in an organization. For example, most organizations need knowledge in finance in order to ensure their financial health. Then, the knowledge possessed by the financial group, including individual and organizational knowledge, creates a financial knowledge population. Each dimension of the DICE model may include several activities. These are shown in Figure 2 and will be discussed further in this paper.

2. Knowledge Distribution

Population distribution in ecology is a snapshot of a community and a good allegory of understanding the "what is" and the "how is" of the community at that particular moment. Similarly, we can define knowledge distribution as a snapshot of the knowledge community at a given time.

In many cases, the success of an organization is determined by the quality of a particular type of knowledge and by the composition and distribution of many different types of knowledge.

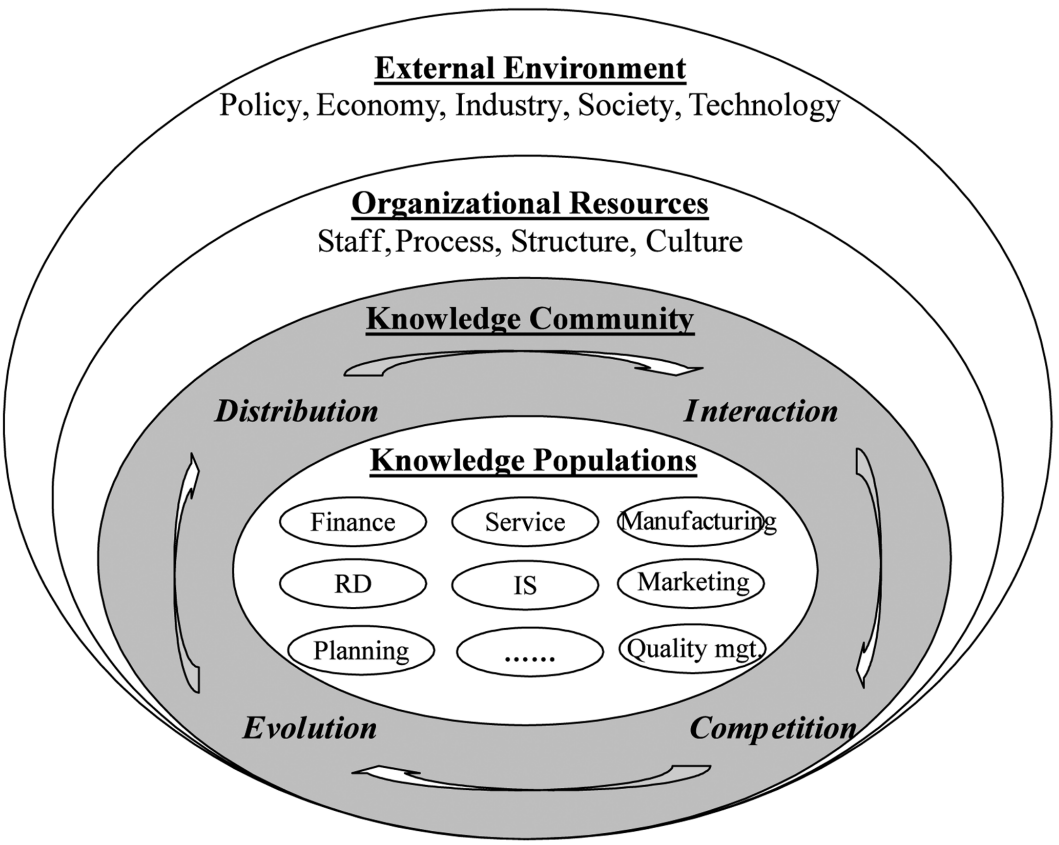


FIGURE 1 — Conceptual Illustration of the Knowledge Ecology in an Organization

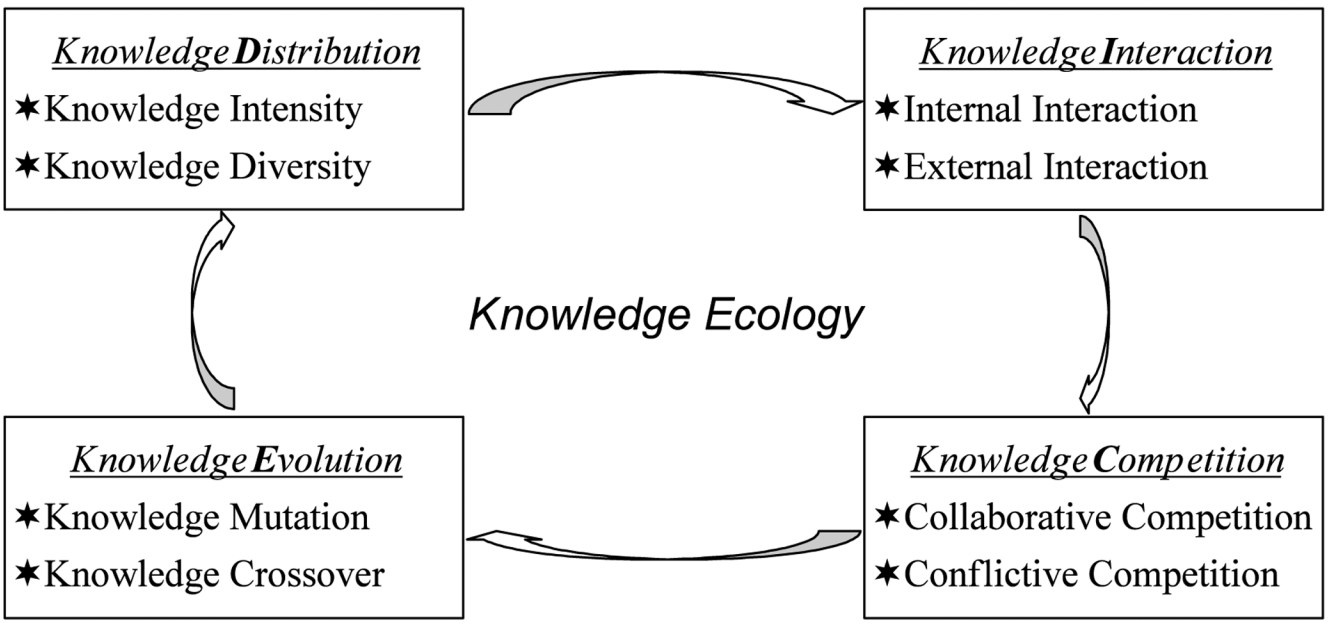


FIGURE 2 — Major activities in the DICE Model

How an organization chooses a knowledge configuration to meet its environment, is a challenging issue for study. The facts of this strategic configuration choice often generate more impact on the survivability of an organization than the process of managing a single type of knowledge. Several years ago, Integrated Circuit (IC) design was a function of many electronic manufacturers before design houses chose to concentrate on design knowledge. This choosing has made IC design a new industry that is separate from the original business.

A *Knowledge map* is a tool for capturing and representing organizational knowledge in an organization from abstract concept to reality [34, 61]. In addition to knowledge source, two aspects are important in an organization's knowledge map: knowledge intensity and knowledge diversity. They allow the effect of knowledge distribution on organizational performance to be monitored.

(1) Knowledge intensity

Knowledge intensity is the relative strength of a particular knowledge population as compared to others. The stronger a particular knowledge population, the better chances this knowledge population can perform better than its competitor [21]. In addition, the whole knowledge community will get better competitive advantages. For example, if an organization is particularly strong in product design; this means that the knowledge population of product design has high knowledge intensity.

(2) Knowledge diversity

The concept of diversity is popular in many scientific disciplines. Financial managers adopt diversity to maintain a portfolio of risky assets to reduce drastic fluctuations of its value. Diversity in knowledge reflects the equitable measure of the species in the knowledge community [7]. In addition to the measurement of strength, diversity provides another view of the knowledge community.

In previous research, several studies have investigated related issues. Rulke and Galaskiewicz [53] found that group performance was contingent on the heterogeneity of group members. Groups whose members have more diverse knowledge configuration outperform those whose members are more homogeneous [53]. Griffith et al. [24] studied the relationships between different types of knowledge and knowledge transfer in virtual teams. The distribution and form of knowledge across individuals, teams, and the organization may be changed by the combination of information technology and the virtual team's work. At the organizational level, Gold et al. [21] found that both knowledge infrastructure and knowledge process capabilities were able to enhance organizational effectiveness [21]. Liang et al. [39] studied the role of knowledge diversity in software project management, and found knowledge diversity would have significant effects on team performance. These findings indicate that knowledge distribution is a factor of importance for future researchers.

3. Knowledge Interaction

While knowledge distribution shows the static situations of a knowledge community, knowledge interaction and evolution represent the dynamic behaviors of knowledge populations in an organization. Knowledge interaction conveys the information flow across different knowledge populations and information technology (IT) is paramount in constructing an infrastructure to support the breadth and depth of knowledge flow [1, 33, 40].

Interaction among knowledge populations is similar to "knowledge sharing" or "knowledge process" in KM research, in which there are many forms of interactions. Most knowledge creation activities such as socialization, externalization, combination and internalization are in the ascension of knowledge proposed by Nonaka [49]. These can be considered different forms of knowledge interaction.

The form of knowledge interactions can be personal communications or personnel flow within the community or outside the community and are called internal interaction and

external interaction. Madsen et al. [42] tracked the flow of personnel within and across organizational boundaries and geographic boundaries to find that the different sources: intra-firm, cross border intra-firm, local inter-firm, and cross border inter-firm, of personnel flow increased an organizations retention activity. Lin et al. [41] studied the impacts of knowledge sourcing on learning outcome. The knowledge sourcing is defined from people's own experience and from the experience of others.

(1) Internal interaction

Internal interaction means people share information and knowledge within a community. Internal interaction between knowledge populations allows information and knowledge to be shared among different populations in the same organization. Hansen [29] proposed the concept of knowledge networks, a type of internal interaction infrastructure, to explain why some business units benefit from inter-unit knowledge sharing in a multi-unit organization. The results suggest that joint consideration of related knowledge and lateral network relations is needed to explain the benefits of inter-unit knowledge sharing in an organization.

(2) External interaction

External interaction means a knowledge population communicates with other knowledge populations outside the organization this is a common practice and allows knowledge to be introduced into an organization from outside sources. Previous research has found outside sources of knowledge are valuable for the innovation process and increases productivity [13, 15, 60]. Cummings [14] showed that external knowledge sharing was strongly associated with performance, when work groups were more structurally diverse. In addition, Gottschalk [22] argued that knowledge management should transcend organizational boundaries, and increase knowledge transferring will improve partnership with others.

4. Knowledge Competition

When an organization is under resource constraints, different knowledge populations will need to compete in order to grow. The competitive behavior among knowledge populations will influence the organizations ability to manage its knowledge effectively [17, 21, 38]. An organization will have to choose one product for commercialization between two prototype development teams. This means two knowledge groups are competing for survival. The loser will need to be dismissed or re-organized. It is common that the production department and marketing department compete for their proposals to be accepted. Competition makes strong populations grow up and weak populations turn down at the moment. Knowledge competition can be collaborative or conflictive.

(1) Collaborative competition

Collaborative competition means that knowledge populations will share certain common resources or values while they compete. This means they will move towards a win-win resolution for all involved parties. Since collaborative culture will reduce the fear and increase openness to others, it was found to affect knowledge sharing performance through increased knowledge exchange [32, 45]. Lee and Choi [36] reported a positive effect between collaborative organizational culture and knowledge process. Nelson and Cooprider [47] argued that knowledge sharing could only be archived through mutual trust, an element of collaborative culture. Palanisamy [51] suggested a knowledge-friendly organizational culture as a catalyst for the KM process. These findings imply that collaborative competition between knowledge populations is helpful for knowledge sharing and KM in an organization.

(2) Conflictive competition

Conflictive competition means that knowledge populations will have direct confrontation for common resources or values while they compete. This means that any gain in one population comes from the loss from other populations. From this view, the knowledge populations that rely on the same resources for survival or the niche overlap, is critical in determining the degree of competition. Significant niche overlap commonly results in intense competition.

Conflictive competition will reduce mutual understanding among organizational members. As a result, this lowers the levels of knowledge sharing even with the support of IT. Orlikowski [50] found that in competitive and individualistic organizational cultures, where few incentive or norms for cooperating or sharing of expertise existed, the groupware did not stimulate collaboration. There are conflicting findings to this view. Burgelman [9] suggests that a proper level of internal conflict could help adjust strategy-making in an organization and is helpful to organizational performance. Therefore, we can conclude that a level of conflictive competition is helpful, but it should not exceed specific limits.

5. Knowledge Evolution

Evolution is a strategy that a population uses to cope with the pressure of environmental variability. It is the dynamic capability, to which every organization should strive to integrate, build and reconfigure their competences under a rapidly changing environment [57].

Zollo and Winter [62] suggested learning mechanisms would have an impact on dynamic capabilities in an organization and cause an evolution of knowledge. They also proposed a knowledge evolution cycle concept to investigate the evolution of organizational knowledge through a series of stages chained in a recursive cycle.

Van den Bosch et al. [59] proposed a framework for the co-evolution of an organizations absorptive capacity with its knowledge environments. The framework offers an explanation of how the co-evolution of knowledge environments, with the emergence of organization forms and blending abilities are suitable for absorbing knowledge. Bieber et al. [8], developed architecture for a community knowledge evolution system and the system could be used to improve many members' tasks in a virtual community. These works indicate that the evolution of knowledge will be an interesting research issue in KM.

Menon and Pfeffer [44] suggested two knowledge sources that are the driving forces of knowledge evolution: internal and external. The competition pressure coming from internal colleagues or external rivals drives these two types of knowledge sources. In knowledge evolution, two major forces will cause variation of the population and affect the evolutionary patterns: knowledge mutation and knowledge crossover [23, 44].

(1) Knowledge mutation

The concept of knowledge mutation is derived from genetic mutation, which stands for the random change of the occurrence of a particular gene in a species. Genetic mutation can be recognized as an internal force to change the population. In knowledge ecology, knowledge mutation is defined as changes or enhancement of knowledge. This is motivated by internal forces, such as the outcome of a research and development (RD) project and self-examination. New knowledge derived from internal mutation will be innovative and significantly different from old knowledge. Shih et al. [55] emphasized the importance of internal environmental auditors in an organization, to serve as a trigger for internal mutation. They suggest that the better an organization improves its internal environmental management mechanism, the better its financial performance will be. This environmental awareness helps the continuous update of the operating knowledge and results in performance enhancement [55].

(2) Knowledge crossover

Similarly, the concept of knowledge crossover is adapted from gene crossover, one of the most important mechanisms for genetic variation. Gene crossover is defined as the interchange of sections between pairing homologous chromosomes during the prophase of meiosis. Meiosis is the cellular process that results in the number of chromosomes being reduced to one half. It is a method used to vary the chromosomes from one generation to the next. In knowledge ecology, knowledge crossover is identified as changes or enhancements of knowledge initiated by forces outside a knowledge community, such as acquiring a patent license or hiring a new researcher from a competitive organization.

6. Summary of the DICE model

In summary, the DICE model consists of four major features to represent the knowledge ecology of an organization: distribution, interaction, competition, and evolution. For knowledge distribution, the intensity and diversity are two major components. Knowledge interactions will occur within or outside an organization. Competition will either be collaborative or conflictive. Where a collaborative culture has better impact on organizational performance, evolution will either be through internal mutation or knowledge crossover with outside organization knowledge.

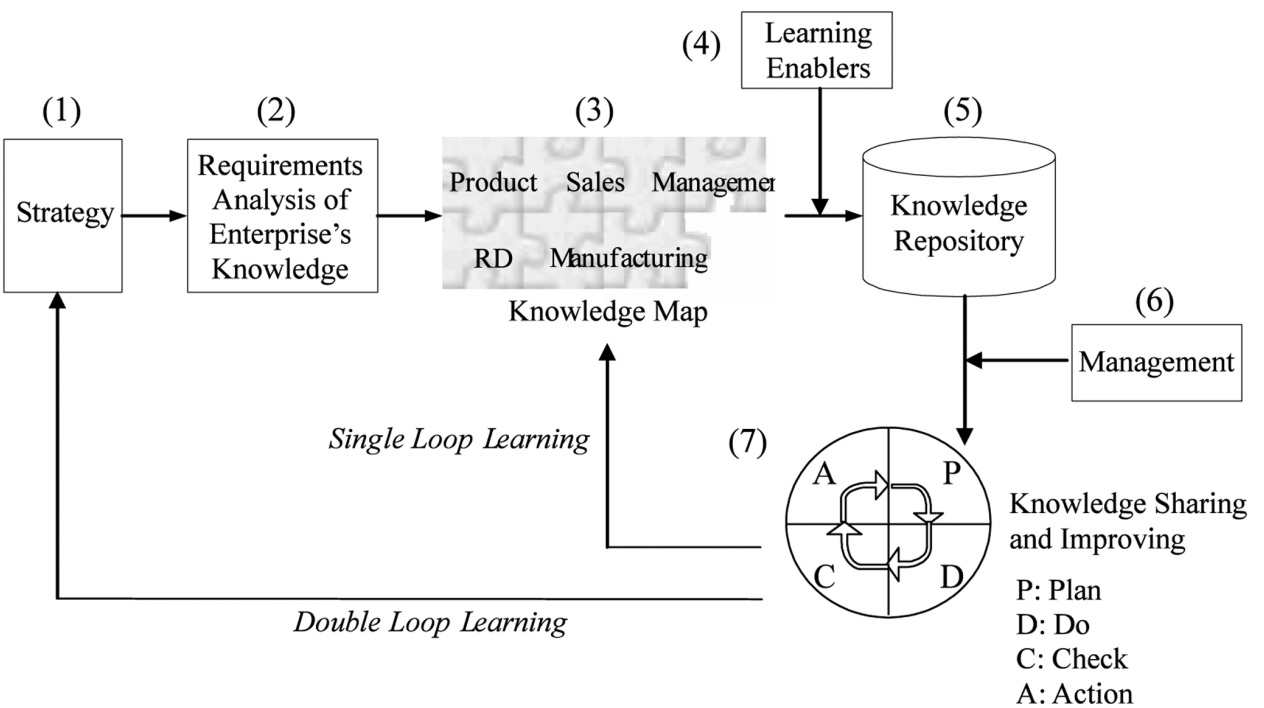


FIGURE 3 — A Practical KM Model in the Semiconductor Industry (Chou [12])

Stage 1: Identify the core strategy and organizational capabilities, with an emphasis on finding the strategic role of core knowledge.
Stage 2: Based on organizational strategies, analyze what types of knowledge that enterprise must gain for competition.
Stage 3: Construct a knowledge map according to the identified organizational capabilities. The knowledge map shows the distribution of knowledge and demonstrates its organizational competitiveness.
Stage 4: Cultivate a learning culture and establish a learning/sharing group to enhance the knowledge capability of the organization through learning enablers.
Stage 5: Codify and document knowledge, to save in the knowledge repository for sharing. The knowledge repository includes various documents, including problem-solving documents, customer-complaint and settlement documents, discipline training documents, project reports, and with other miscellaneous documents.
Stage 6: Institutionalize knowledge management to encourage a lifelong learning culture in the second learning loop.
Stage 7: Apply the stored knowledge to the solving of new problems by the PDCA process. The experience gained during this course may be used to revise the organizational knowledge map, the organizational strategies and the core knowledge.

In Section IV, a real-world case study is explained to illustrate how this model can be used to demonstrate the knowledge ecology of an organization.

IV. A CASE STUDY

1. Knowledge Management Mechanism in the Selected Case

The research case uses Company Z, the largest semiconductor packaging and testing company in the world with different types of shares traded on the Taiwan Stock Exchange, NYSE and NASDAQ. Engineers in the company spent considerable time solving repetitive problems on their product line and new problems often emerged before the old problems were completely solved. To reduce the repetitive effort and share the experience among employees, the company launched a knowledge management project in the late 1990's. Its KM team adopted a "double loops knowledge management framework" that includes six major stages detailed below. This framework is shown in Figure 3.

In the company, a computer-based KMS was used to manage all knowledge documents provided by its employees. New documents must be discussed and evaluated within a knowledge group. Once approved, the document will be uploaded into the KMS and shared by the entire organization.

2. Knowledge Groups in the Case

KM at Company Z is centered at many knowledge groups in various departments. Each department manager is the leader of the knowledge groups. There were approximately one hundred active knowledge groups in the company at the time of this study. The knowledge groups help to streamline the learning curve for new inexperienced employees and help reduce the chance for errors to occur repetitively. Each knowledge group is a knowledge population in our ecology model. Therefore, we can use the DICE model to portray its knowledge ecology.

Knowledge population is the basic element for knowledge ecology. By definition, a knowledge population refers to "a composition of knowledge capability with the same features, including personnel, documents and systems in an organization." In this research case, employees working on tasks with similar features form a knowledge population, called a knowledge group.

Manager C, the chief knowledge officer, built the whole KM architecture. He mentioned the way they differentiated knowledge groups:

> *We differentiate knowledge groups by departments and tasks. Each group encompasses approximately thirty members, including engineers such as project engineers, infrastructure engineer and, material engineers. Depart-ment managers are leading the groups. Because the tasks are highly related to each other within a group, experiences and expertise can be exchanged effectively.*

The attitudes of department mangers are crucial to the success of knowledge groups and the success of knowledge groups is the key to the success of the company's KM. As pointed out by Manager A, the leader of a knowledge group:

> *Department managers' attitudes are critical to the performance of a knowledge group. If the department manager is very active, the group will be successful. In addition, the leader has to convince engineers to buy the benefits of knowledge management.*

Manager G, another group leader, stressed the importance of trust and commitment. He mentioned:

> *Engineers' commitment to self-learning and self-improvement will contribute to the success of knowledge groups. Members are required to attend group activities. Trust on each other can be developed in the process. Trust is a motivator to establishing knowledge groups. Rewards and discipline systems should be clear.*

As knowledge group is the foundation for KM, the performance of knowledge groups directly impacts the implementation of KM in the organization.

3. The DICE Model in the Case

In this section, we apply the DICE model to show KM activities in the case.

(1) Knowledge distribution

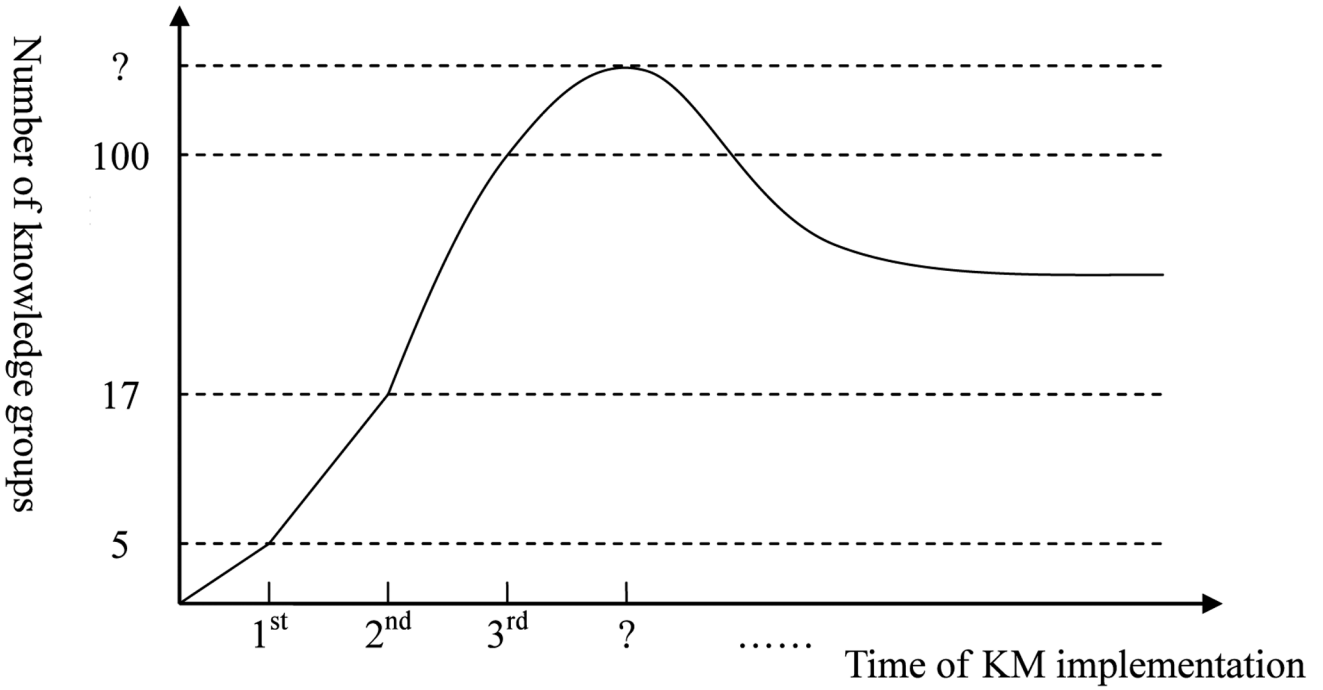
In our research case organization, the number of knowledge groups has grown from five in the first year of implementation to over a hundred in the third year. Table 1 summarizes the growth in the first three years.

As the number of knowledge group's increase, each group becomes more professional and the knowledge intensity is reflected in the groups' abilities to solve problems. However, Manager C mentioned that not all group functioned well. Different group tended to build on their own strengths. Those who could not build enough knowledge strength could not survive. The number of groups will eventually stabilize to an upper limit, as shown in Figure 4.

TABLE 1 —
The Growth of Knowledge Groups in the Case Firm

KM implementation	# of knowledge groups	The features of knowledge groups
1st year	5	Five business units were selected to be the experimental units for the KM project.
2nd year	17	The CEO asked for an expansion to the whole company. KM became compulsory in 17 business units.
3rd year	More than a hundred	KM mechanisms had been institutionalized to support daily operations and internalized as organizational culture. KM had penetrated into all business units.

FIGURE 4 — The Predicted Growth Curve of Knowledge Groups



The growth of groups shows a rapid increase in diversity. As stated by Manager C:

> *At the beginning, we focused on a few important knowledge groups and then started to penetrate into the whole company. We hope to carry out knowledge management in every business unit and to acculturate knowledge management in the organization, whereby each department can internalize knowledge management into their daily management routines.*

Every category of knowledge has its value to a business. Therefore, maintaining a proper level of diversity is necessary. Procurement may not be critical to the profitability of a bank, but every bank still needs to manage procurement knowledge properly. The research organization strained to maintain a proper balance among the diversified knowledge groups. Manager G stated the following point in our interview:

> *I don't want all of my group members coming from my own department. I hope my group encompasses employees with different capabilities. In this way, each member contributes to problem solving from different viewpoints, which would be helpful for problem solving.*

The above view gradually led to a higher level of diversity in the company, which is good for the organization. From this study, we can put together the following proposition:

> ***Proposition 1****: Managing the distribution of knowledge in an organization is important in knowledge management and the distribution will affect the performance of the organization*

(2) Knowledge interaction

Different knowledge groups may interact with other knowledge groups inside or outside the organization. For example, the manufacturing group may interact with the design team to fine-tune their products for better production efficiency or interact with the suppliers to ensure a shortage-free production schedule. During an interview, Manager G mentioned the effect of internal interaction on the growth and improvement of the knowledge group's capabilities:

> *The emphasis of knowledge management is knowledge sharing. Knowledge management is contingent on the sharing culture within our organization. It is important not only to share knowledge documents, but also to discuss among group members. My members acquire new knowledge through interaction with one another. This tacit knowledge will not be displayed in the document; however, it is valuable to the growth of employees. Because group members know the same knowledge domain, they are more effective in sharing and interacting with one another.*

Manager A also referred to the importance of internal knowledge sharing. He said:

> *If there are two members in a group and each of them has an idea, then they would have two ideas after sharing. This is certainly better than having only one idea for each. The atmosphere of sharing is an important factor to improve engineer's capabilities.*

Members in a knowledge group may also benefit from

continuous sharing and interaction with other groups. Manager A mentioned his cross-department experience:

Many of our daily tasks are cross-department and cannot be solved in a single department. This highlights the importance of inter-group interaction. Group members establish mutual understanding of one another's business via daily interaction, so that they can find their problem-solving partners when needed.

Manager G addressed a method he used to promote inter-group interactions. He said:

I often divide my group, force my members to join other different groups' discussions and bring back their learning outcome. So far, my group is able to attain better knowledge quality this way.

Manager C also mentioned that both intra-organizational interaction and inter-organizational interaction occur very often in the company. He said:

Inter-group interactions, both inter-organization and intra-organization, occur frequently. These interactions are mainly business oriented. When there is a need, groups would find proper partners and collaborate with one another.

The above observations indicate that frequent interactions will result in better knowledge sharing and cohesion in the organization. Hence, we present the following proposition:

Proposition 2: *Both internal and external interactions exist as important mediums for knowledge sharing. More frequent interactions can enhance the quality of knowledge populations in a community.*

(3) Knowledge competition

A special kind of knowledge interaction is competition, which may be collaborative or conflictive. Collaborative competition targets a win-win situation under resource constraints that will benefit the entire organization, whereas conflictive competition will harm an organization. Collaborative competition is common in the case company. Manager A mentioned their problem-solving experiences. He said:

Once we receive customer complaints about product defects, all related departments got involved and collaborated to fix the problem. Solutions from different groups were analyzed and compared to find the best solution, before we identified which unit was responsible for the problem. People in our company are very cooperative

Conflictive competition refers to confrontation behavior. Although this exists, it will not occur very often in a well-managed organization. Manager C mentioned the following in our interview:

We foresaw the existence of competition among different knowledge groups at the beginning. We were concerned of the unwillingness to share knowledge among group members due to internal performance competition. However, through a carefully designed management system, we have reduced the competition between groups to a certain extent. We include knowledge sharing as an important indicator in the performance appraisal. Competition might still occur behind the scene, but most employees are required to share knowledge under the current system.

Therefore, we find that collaborative competition relies on a cooperative culture, while conflictive competition must be controlled by the performance appraisal scheme. We propose the following proposition:

Proposition 3: *Knowledge competition can be managed by fostering a sharing culture and enforcing a sharing-related performance evaluation scheme.*

(4) Knowledge evolution

Knowledge evolution of the case company has two foci. One is the rapid increase of knowledge groups, as shown in Table 1 and Figure 4, and the other is the sources for knowledge evolution. The company uses both internal and external sources to facilitate its knowledge evolution to meet environment changes and market competition. Knowledge mutation refers to innovation within the organizational knowledge populations and knowledge crossover refers to the evolution that involves combination with knowledge acquired from external knowledge populations.

Manager C argued that his group's primary goal for KM was to motivate group members to enhance themselves. He said:

In addition to On the Job Training (OJT), we rely on the concept of ownership to facilitate self-enhancement in the knowledge group. Ownership refers to the notion of authority and responsibility. Everyone should take the responsibility in their field and should assume the accountability when there is a problem. Certainly, excellent performance deserves appropriate rewards.

Ownership defines the boundary of responsibility of an individual. If an individual makes a mistake within this responsibility boundary or repeats the same error having been reported in existing documents, the person will be penalized. In contrast, sharing valuable knowledge is encouraged and monetary reward is offered. This incentive mechanism pushes document owners to try their best in enhancing document quality. Manager A commented on how his group pushed members to be responsible for the knowledge documents they produced:

We require the group members to publish knowledge documents. Members also evaluate the documents. These evaluations are the basis for performance evaluation. A high quality document often is the result of continuous discussion and refinement by my teammates. Sometimes, we cooperate with people from other departments to solve a problem. In this way, we learn new knowledge from other departments.

The learning may also come from external organizations, such as suppliers and customers. Manager C mentioned an example where knowledge growth was driven by input from external organizations. He stated:

Considerable new knowledge, such as new technology infrastructure and new material for manufacturing, is acquired from other firms. Sometime we invite them to give a talk in our company and to provide consultation for us. This knowledge exchange enables us to keep track of knowledge progress outside my company and enhance our capabilities.

Typical approaches to acquire external knowledge include seminars, licensing, consultation and new hiring from other related organizations (such as vendors and customers). Different approaches have their pros and cons and must be considered carefully. Our case company shows that both internal and external sources of knowledge are important to the knowledge evolution and enhancement. Therefore, we propose the following proposition:

Proposition 4: *An organization need to take advantage of both internal and external knowledge sources to enhance the quality of organizational knowledge over time. Internal evolution can be fostered by policy enforcement, while external acquisition must be carefully calibrated.*

4. Summary of Findings

In summary, the case study allows us to observe the following facts in its knowledge ecology:

(1) The knowledge populations affiliated with individual functional units grow very fast and performed well as basic knowledge units in the organization.
(2) A proper distribution of knowledge populations is important to the success of organizational KM. Without adequate strength, those populations would not survive, but the failure of a few knowledge populations should not affect the overall effectiveness of the KM project.
(3) Mechanisms must be designed to encourage interactions among knowledge populations inside and outside the organization. Developing a sharing culture is important for better knowledge interactions.
(4) A certain degree of competition among knowledge populations is beneficial. It is useful to promote more collaborative competition, rather than conflictive competition.
(5) Knowledge will evolve over time through new knowledge creation by internal populations or a combination with new knowledge acquired from outside sources. It needs to be more careful when evolution relies on outside knowledge sources.

Knowledge ecology based on the DICE model has provided a new perspective to investigate the knowledge management in organizations. It suggests a macro view to manage knowledge assets and a dynamic view to maintain the competence of knowledge resources in uncertain environments. In the research case, for survival, an organization should maintain a healthy knowledge distribution among various knowledge groups. By different types of interaction and competition, the knowledge groups would change. Finally, they would evolve into new type of knowledge assets to cope with the competitive pressure and keep the competition advantages.

V. DISCUSSION AND CONCLUSION

We have presented a new approach to KM that examines the organizational knowledge from an ecological perspective. The proposed DICE model portrays the knowledge ecology of an organization from the distribution, interaction, competition, and evolution of its knowledge populations. A case study was conducted to support the new approach.

The contribution of this study is multiple faceted. First, this is one of the initially studies to bring ecological theories into the analysis of KM. With more investigations and deeper understanding, this approach will provide insight into organizational KM. Second, this new perspective opens many new research opportunities for further investigations. Since knowledge distribution triggers a natural topic of research, an example of future research would be whether different knowledge distributions would affect organizational performance or productivity? There are many new research areas that need further investigation.

From a strategic point of view, another interesting issue is "how can" and "whether or not" an organization can maintain an optimal portfolio of its knowledge assets. Traditional KM literature does not differentiate the relative importance of different types of knowledge in an organization. However, this may not be the case in reality. An organization may be more cost-effective to target at a few core knowledge, rather than treating all knowledge equally.

The framework and findings from this case study provide useful guidelines for managing knowledge from the ecological perspective. For organizations that have implemented KM, they may switch their attention from the KM process of socialization, externalization, combination, and internalization, to the new dimensions of knowledge distribution, interaction, competition, and evolution. Organizations should pay attention to the sources of knowledge that trigger the knowledge evolution and whether internal or external interaction is more effective for the organization.

Opportunities for future research are abundant. More IS research can utilize the ecological framework to further expand the scope of KM research. We also need to sharpen the theoretical framework and conduct empirical studies to evaluate the propositions put forth in this article. Finally, it will be interesting to examine the "whether" and the "how" IS/IT can affect the knowledge ecology in an organization.

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