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An Economic Benefit Model for Knowledge Creation

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Abstract

The role of knowledge creation within organizations increases in importance within a knowledge economy. Unlike the industrial economy, which inspired basic economic theory, the knowledge economy collapses the time frame for economic agents to obtain relevant knowledge with which to make competitive resource allocation decisions. Further, much knowledge creation still occurs today in an inefficient and unstructured fashion within organizations. In this paper, we examine briefly the process of knowledge creation. We posit that knowledge creation yields an economic benefit to the organization and present an analytic model which examines how formal knowledge creation embedded in formal learning processes provide this benefit. Our model provides an inducement for organizations to increase their management and participation in knowledge creation processes.

Keywords: Knowledge management, knowledge creation, modeling, organizational learning, knowledge economy

1   INTRODUCTION

Organizational dynamics relating to knowledge and knowledge creation have economic, social, and political impact. From a business-domain perspective, "one of the major challenges for management is to understand the role of knowledge and learning for organizational change and business success" (Pawlowsky 2001). Management must also apply that understanding in such a way as to produce an economic benefit for the organization.

Knowledge supplies the motivation for much of the organizational dynamics that have an economic basis. Underscoring the role of knowledge to business, Hitt et al. (1998) note, "The one sure source of lasting competitive advantage is knowledge." Creating sustainable competitive advantage is enabled by either the reduction of expenses, or by an increase in product quality (Ofek and Sarvary 2001).

While diffusion of innovations and best practices have been a significant challenge for practitioners and researchers for over 30 years, the knowledge economy exacerbates the situation further, requiring accelerated organizational learning of these innovations in advance of the competition (Zell 2001). Knowledge workers differentiate themselves from industrial workers by the dynamic nature of their tasks and responsibilities. For example, a typical assembly line worker of the industrial economy performed relatively simple and static activities, performing them repetitively and consistently. Experience played a major factor in a worker's competence. Knowledge workers, however, find that tasks and/or content change frequently.

For example, managers, today, find increasing complexity in their roles.

Amidst this myriad of global change individual managers and executives are being asked to change their approach to running their operations and managing people. The "new" managers we are told must learn to be coaches, team players, facilitators, process managers, human resource developers, visionary leaders and entrepreneurs (Senge 1990).

For programmers, new knowledge precedes experience in organizational value. Programmers cannot rely as much on experience as did the COBOL programmers of the 1970s. With the exception of the Y2K anomaly, COBOL programmers no longer are highly prized and respected because of their extensive experience; industry regards them as dinosaurs. Even if they have learned Java, this is not enough, as a Java programmer must expand now to JSP, J2EE, and even XML integration requirements. Therefore, while experience remains a variable in measuring competence and value, knowledge content, skills, and other factors, such as motivation and attitude, also reflect a knowledge worker's competence. Knowledge has further been elevated in importance with the knowledge-based economy with regard to product life cycles. In the previous industrial economy, generations of competitive products were measured in decades; they now occur within only a few years.

Some aspects of the current economy do not appear to adhere to the precepts developed under basic economic theory, though. To elaborate, in reviewing the former industrial economy, the nature of organizational objectives and worker behaviors were much different than what we witness today: organizations sought equilibrium and succeeded by capturing economies of scale. Production followed a Frederick Taylor, repetitive, assembly-line approach. Sales, senior management, and marketing understood the customer, but few others in the organization did. Large corporate management teams generally consisted of venerable, gray-haired or balding, Anglo gentlemen. Workers believed their employment was protected until retirement, and an employee's highest wage-earning years were those just preceding retirement.

Now, move forward to the knowledge-based economy. The period of the late 1990s is a particularly interesting interval with which to examine the organizational dynamics of this new knowledge-based economy as it contrasts to its predecessor (Norris 2001):

- On average, companies were projected to lose half their employees in 5 years

- Workers quitting their jobs for better offers would jump from 6 million in 1995 to a projected 17 million in 2000

- A young graduate was projected to have nine jobs in approximately 10 years

- Replacing a worker cost roughly half of that person's salary, in addition to the burden and stress put on colleagues and the organization as a whole

- The uncalculated costs of unwanted turnover (loss of talent, customer satisfaction, employee morale, productivity and quality) were projected to exceed any costs that the organization normally tracks

Further, senior management ranks increasingly include disparate races and genders, with more people needing more detailed knowledge about the customers. With such organizational churn, equilibrium and stability are not easily achieved, perhaps not even desired. It is possible that this churn could be minimized with increased, and formal, knowledge creation processes. However, during turbulent times, management often reduces these very processes, feeling unsure of their benefits.

We suggest that in the framework of a dynamic, knowledge-based economy, organizational learning provides an economic benefit, in spite of the complexities involved in establishing a formal learning program. In other words, we conjecture that it is economically beneficial for organizations in today's knowledge-based economy to adopt a formal learning program and facilitate continuous knowledge creation within the organizations. To this objective, we propose an analytical model examining how knowledge creation embedded in formal learning processes provides an economic benefit to the organization. More importantly, with further sensitivity analysis based on our model by analyzing the relationship between various factors (e.g., lowest current competence versus highest current competence of workers, shortest task times against those with the longest duration, learning programs with least intensity against learning programs with the greatest intensity, different decay rate of workers' competence, and different worker gain rate from participating learning programs), we can gain important insights of managerial implications. It is important to notice that if management does not carefully foster knowledge creation processes, under some circumstances (e.g., intensity of a learning process and subsequent increased competence is outweighed by decay rate of workers' competence) knowledge creation will *not* result in more economic benefits to the organization.

The flow of this paper moves us from an intrinsic benefit to an economic one. In the following section, we review existing research surrounding knowledge, knowledge creation, learning, and innovation. Next, we describe organizational knowledge dynamics in the knowledge-based economy. Finally, we present a model for knowledge creation and a numerical example. The model posits that information workers gain by participating in the knowledge creation process, and a net benefit to the organization is determined with regard to the intensity of this process. The numerical example demonstrates our concept and provides an understanding of how much an organization may benefit from a continuous knowledge creation process.

2 LITERATURE REVIEW

Knowledge, as a construct beyond information and data, is emerging more frequently than ever before as a topic of research for information systems (Grover and Davenport 2001). What is knowledge? From a computer scientist's point of view, knowledge may be nothing more than a relationship between knower and a proposition (Levesque and Lakemeyer 2000); for example, *Janet knows that wine ages more rapidly in high temperatures*.

Piaget (1969) describes three types of knowledge: (1) physical knowledge, which are accurate, empirical perceptions about physical properties of objects, such as size, color, and texture; (2) logical-mathematical knowledge, a more abstract concept relating to actions upon objects, such as mass, volume, or speed, and (3) social knowledge, which is constructed based upon one's cultural group. The latter includes language, culture, moral rules, history, and symbol systems.

Von Krogh et al. (2000) consider knowledge mutable and capable of taking on many faces in an organization. They focus on knowledge enabling and specify four critical elements: (1) knowledge is justified true belief, (2) knowledge is both explicit and tacit, (3) effective knowledge creation depends on an enabling context, and (4) organizational knowledge involves a five-step process. The organizational knowledge process is as follows: (a) tacit knowledge is shared, (b) creating concepts, (c) that once justified (d) are constructed into a prototype and (e) disseminated further into the organization.

Davenport and Prusak (1997) refer to knowledge as a "fluid mix of framed experience, values, contextual information, expert insight and grounded intuition that provides an environment and framework for evaluation and incorporating new experiences and information."

Polanyi (1983) describes knowing as including both practical and theoretical concepts, the "knowing what" and the "knowing how." He further characterized these two dimensions, respectively, as tacit and explicit knowledge. Tacit knowledge is unexpressed knowledge; it is what we know when placed into a particular situation, but cannot express (readily) until the context becomes apparent. The process of expression transforms it into explicit knowledge.

Nonaka (1991) and his colleagues (Nonaka and Konno 1998; Nonaka and Takeuchi 1995) describes tacit knowledge as the only lasting source of competitive advantage. While a goal of an organization is to transform tacit knowledge into explicit knowledge so that it can be efficiently shared within the organization, once made explicit, knowledge loses its original value. Explicit knowledge can be copied, shared, or stolen by rivals.

Tiwana (2000) refers to knowledge as actionable information. She refers to the relationship between Xerox PARC and Microsoft: both had virtually the same information, but Microsoft knew how to put it into action. She further emphasizes that knowledge management is not knowledge engineering. The business context of knowledge management absorbs people into the information system; knowledge engineering objectifies people outside of the produced system. With people as part of the total system, context becomes more relevant and thus furthers the productivity of knowledge creation.

2.1 Learning and Knowledge

Knowledge can be viewed as a result with learning as the process leading to this result (Senge 1990). Cognitive science assists both by addressing human intelligence and seeking to understand how it works (Anderson 1995).

Much learning occurring in organizations is unstructured. Whether sitting in cubicles next to each other, or even in informal communities of practice (groups of people with common interests [Wenger and Synder 2001]), individuals learn as much in informal channels as they do in formal settings, such as training sessions, meetings, and conferences. Argyris (1994) even suggests that single-loop information such as surveys and focus groups may block organizational learning. Single loop systems, he

explains, have the effect of encouraging employees to look upon their role as criticizing management practices and the role of management is only to fix the identified problems. In a double loop system, he contends, organizational learning is enhanced by encouraging not only an evaluation of objective facts, but also of the motives and situations that gave rise to those facts. Argyris contends that organizational learning is enhanced by systems that encourage individuals to consider their own behaviors and how those behaviors can directly address challenges and opportunities. The economic benefit that we demonstrate with our model serves to motivate organizations to develop a system that can enhance organizational learning and individual learning in a formal and continuous manner.

Senge observes that learning-by-trial-and-error does not enhance organizational success. He concludes that learning disabilities are fatal in organizations and that they preclude the organization from surviving to half the age of the average individual. Senge encourages organizations to think of learning from a systematic perspective. Organizations should encourage individual commitment to life-long learning. They need to encourage team learning to increase the sublevel collective intelligence typical of group decisions. Learning is enhanced by mental models (Anderson 1995), and Senge encourages managers to foster shared mental models of the organization, their markets, and their competitors. Finally, a genuinely shared vision of the organization inspires commitment. Thus, these elements encompass Senge's characteristics of a learning organization.

2.2 Economic Models

We have seen an emergence of relative consistency within the community of knowledge researchers with regard to learning and knowledge creation. But, how does this benefit the organization economically?

The dynamics of the knowledge economy appear to aggravate the early economic notions of equilibrium analysis. Much of rational, economic theory relates to the ability of economic agents to have time to absorb all relevant knowledge in order to make rational decisions. Decision makers cannot rely on these principles of rationality (Boerner et al. 2001). In the knowledge economy, actions may need to be executed based upon uncomfortable levels of uncertainty, relying upon increasing levels of tacit knowledge, which may take the form of instinct, insight, and hunches (Nonaka and Takeuchi 1995). Whereas bounded rationality as defined by Simon (1957) relaxed the model of rationality by substituting satisficing goals over maximizing goals, a knowledge-based rationality may also need to soften the requirement for a known set of conceivable outcomes to allow this known set to encompass tacit, as well as explicit, knowledge.

2.3 Innovation

Innovation is largely an organizational property with an intimate relationship between innovation and learning (Child and Heavens 2001). An innovation, though, relates to the introduction of something new, so while in a learning context, anything new is good, in a business context the economic aspects of innovation require that knowledge be created that enhance the productivity of the firm. Therefore, innovation is one of the goals of knowledge creation.

2.4 Technology

Within a technology-support context, information systems, having progressed from automated transactions along with storage and retrieval of data and files, are only beginning to expand beyond the scope of explicit knowledge (Grover and Davenport 2001). Information systems theory has been particularly weak relating to the transformation of tacit to explicit knowledge (Edgington and Chen 2002), and the tacit transformation framework still lacks sufficient research to explain questions relating to how an organization

- identifies valued tacit knowledge (once expressed)
- finds it quickly among a large set of employees
- formalizes processes encouraging repeatable tacit transformation
- facilitates the process of transforming tacit knowledge with information systems technology

In addition, the tacit transformation framework still lacks sufficient research relating to valuation models. The wealth of technology within information systems should allow for some contribution to these questions, but, as yet, little research has been done.
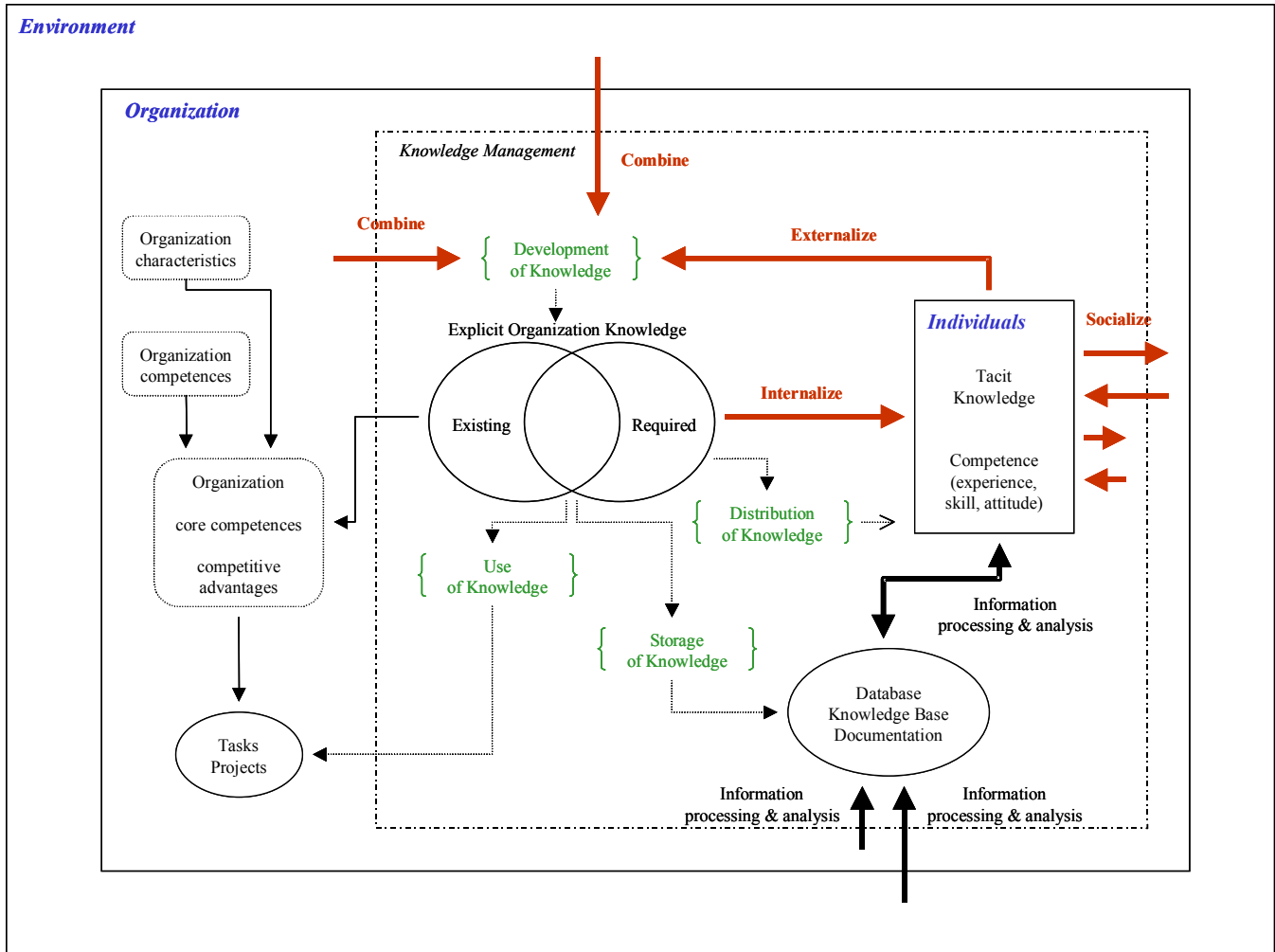
Figure 1. Organizational Knowledge Dynamics

3   ORGANIZATIONAL KNOWLEDGE DYNAMICS

An organization in today's business environment needs to engage in effective knowledge management in order to compete and succeed. Generally, knowledge management involves processes of development of knowledge, distribution of knowledge, use of knowledge, and storage of knowledge (Boekhoff 1996). As depicted in Figure 1, organizational knowledge dynamics are complex, involving interaction from external sources (i.e., environment) and within the organization. We can examine these dynamics further and suggest appropriate technology to assist them.

An organization continuously develops knowledge to enrich existing knowledge (e.g., core competencies and competitive advantage) and at the same time fulfill required knowledge (e.g., to support new strategic objectives). All of the organization's explicit knowledge, theoretically, can be stored in a database, knowledge base, documentation, manuals, etc. The organization's explicit knowledge can also be distributed (diffused) to workers for them to gain more individual experiences and skills. This organization's explicit knowledge, organization characteristics, and organization competence are integrated as the organization's core competencies to complete necessary tasks and projects in order to survive and grow.

Continuously developing knowledge as a source of competitive advantage is fundamental and crucial to an organization. A knowledge spiral results in the theory of organizational-based knowledge creation (Nonaka and Takeuchi 1995) by the interaction of four activities: socialization, externalization, combination, and internalization.

Socialization facilitates tacit knowledge transfer among individuals. It is a sharing activity among organization workers or between organization workers and outsiders (e.g., customers, suppliers, etc.). This process is supported by originating *ba* (Nonaka and Konno 1998) and can be facilitated by IT such as video-conferencing.

Internalization transforms explicit knowledge into implicit knowledge. Workers read manuals, go to training sessions, or learn by doing to enhance their tacit knowledge through comprehending explicit knowledge. It is an embodying activity to improve workers' competencies (experience, skill, and attitude) and to keep up with changes within the organization or from an outside environment. This process is supported by exercising *ba* and can be facilitated by IT such as e-learning.

Combination integrates different sources of explicit knowledge in a more systematic form to meet specific organizational needs. It is a connecting activity to integrate explicit knowledge from different components (people, computer, and documentation) within and outside the organization. This process is supported by systemizing *ba* and can be facilitated by IT with tools such as data mining, knowledge discovery, and workflow management. The combination activity is the one that is most widely supported by current IT tools.

Externalization transforms workers' tacit knowledge into explicit knowledge. It is an articulating activity that improves an organization's knowledge and ultimately strengthens an organization's core competencies. This process is supported by dialoguing *ba* and can be facilitated by IT such as groupware and group decision support systems. The externalization activity has not been researched sufficiently in the past (Edgington and Chen 2002). Within this highly dynamic knowledge spiral, is there a benefit to the organization economically, or is this merely a cost of doing business? We address this question in our next section.

4   KNOWLEDGE CREATION ECONOMIC MODEL

An organization can benefit economically from the knowledge creation process. Workers gain knowledge by participating in either the knowledge generation process (KG) or the tacit knowledge transformation process (TKT), which together comprise the knowledge creation process (KC). KG can be considered as the *internalization* process for the workers and TKT as the *externalization* process for the organization. KC can occur as a result of a formal[1] organizational initiative, such as a mediated brainstorming session, learning session, etc. These KC processes are the focal point of this model.

4.1 Propositions

1. Increased knowledge is a long-term investment in a worker's competence (human capital), where competence is defined as a function of knowledge content, experience, skills, and attitude (Weggeman 1995).

2. Increased knowledge can enrich a firm's existing knowledge, satisfy required knowledge, and strengthen an organization's core competence. This increase supports organizational knowledge dynamics (as described in section 3), which depicts organizational success as a dynamic process of knowledge growth, harvesting, and exploitation.

3. In a quantified scenario, increased knowledge (competence) can reduce task completion time and subsequently reduce cost (increase efficiency). We demonstrate how our model supports this proposition in the numerical examples section (section 4.4).

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[1] In this paper, we distinguish between formal, structured, and informal in reference to processes relating to learning and knowledge creation. We intend structured learning or knowledge creation processes to imply a sequence of events as well as a focus, repetition, and intention. Formal learning or knowledge creation processes only require focus, repetition, and intention; the focus is embodied within an objective. Informal learning or knowledge creation processes do not require focus or repetition, only interest and intention relating to some general category or topic. Without repetition, a requirement of Piaget's (1969) learning theory, knowledge is less likely to be retained and, therefore, has an increased decay rate.

Table 1. Knowledge Creation Model Notation

v_j	intensity of the KC process j
ε_{it}	demonstrated competence of the worker i at time period t
$f(v_j)$	gained knowledge for a worker by participating in the KC process j
G_o	highest possible gain of knowledge from participating in any KC process
$h_c(\varepsilon_{it})$	a factor indicating the reduced task time by the worker i with competence ε
δ	decay rate of a worker's competence from period to period
$C(\varepsilon_{it})$	cost to complete a task with competence ε at time period t
C_o	basic unit cost for completing a task
T_k	normal time units needed to complete the task k
π_i	cost savings for completing a task by a worker after participating in a KC process
π^*	cost savings for completing tasks by all workers after participating in a KC process

4.2 Notations

We consider the elements of the worker's initial competence, the process of the knowledge creation process, the intensity of the process, and the resulting incremental knowledge benefit accrued to the worker. Additionally, we include a decay factor on worker competence and a benefit consideration for improving the worker's knowledge with regard to a task. These concepts are expanded in the following section with the specific variable notation found in Table 1.

4.3 Formulations

First we consider that each KC process can have a different *intensity* (or *efficiency*). A higher intensity implies more output is produced either from the process or from more input to the worker's knowledge. (An IT-facilitated setting can increase the intensity of the process.) Process intensity (efficiency) is any value between 0 and 1. If a worker does not participate in any KC process in time period (t-1), then v_0 is set to be 0 and is assigned for this worker when deriving the worker's competence for time period t. Therefore, $v_j \in (0, 1)$; $\forall j = 1, ..., J$, and $v_0 = 0$ represents and is assigned to a worker who did not participate in any KC process.

Second, a worker's competence will deteriorate from period to period with the decay rate, δ. (Decay is assumed as a natural state for knowledge-influenced tasks.) At the same time, a worker's competence will increase by participating in any formal KC process. This is treated as a basic incentive for a worker to participate in some KC process in order to have an individual gain on competence (human capital). Other incentives (e.g., compensation for participation, promotion, etc.) can be considered in a more sophisticated formulation. So, $\varepsilon_{it} = (1 - \delta) \times \varepsilon_{i(t-1)} + f(v_j)$, where $f(v_j) = G_o \times v_j$; $\delta \hat{I} (0, 1)$. Another assumption here is that each worker is learning individually and the learning results are independent of time. No knowledge sharing and no knowledge accumulation are considered.

Here, we assume that $f(v_j)$ will have the same value for all employees if they participate in any process with the same intensity. We can add a variable if we try to differentiate $f(v_j)$ for workers with different current competence. For example, we can use a formulation such as $f(v_j) = G_o \times v_j \times O(\varepsilon_{it})$ where $O(\varepsilon_{it})$ is the function that will reflect the degree of increased worker's competence based on the worker's current competence. Normally, we will have a function (linear or non-linear) that is strictly increasing but the marginal increase should be decreasing. That is, the greater a current competence that a worker has, the larger the increase of the worker's competence that will result from participating in a KC process.

Third, we assume that any worker can only participate in up to one KC process in one time period. This assumption can also be relaxed in further study and the formulation just needs to change to $\varepsilon_{it} = (1 - \delta) \times \varepsilon_{i(t-1)} + \sum_{j=1}^{n} f(v_j)$ where n is the number of processes in which worker i participated during the time period. Also, we assume that knowledge gains through participating in different knowledge creation processes are independent of each other and are additive.

In this study, we also assume that a worker's competence can contribute the same efficiency toward the completion of different tasks. That is, ε_{it} is the same for all tasks j. For a future study, we can further set different competence levels for a worker assuming different tasks. We will then have ε_{ijt} representing the competence of worker i for task j at time period t.

Increased competence of workers can help an organization compete in the business environment in different possible ways. For the purpose of demonstrating our proposed concept and quantifying the resulting benefit, we assume that competence affects performance of a worker by reducing the time needed to complete a task by a factor of $h_c(\varepsilon_{it})$. The exponential form for the impact of competence on performance is standard in the learning curve literature (Yelle 1979). Hence, $h_c(\varepsilon_{it}) = (1 + \varepsilon_{it})^{-\gamma}$; $\gamma > 0$ (the learning rate).

The cost of completing a specific task k is determined by the *competence factor*, $C(\varepsilon_{it}) = C_o \times h_c(\varepsilon_{it}) \times T_k$.

The benefit for a firm where a worker participates in a KC process is simplified to be a cost reduction based on the worker's increased competence with the intensity of that process, as shown by $\pi_i = C(\varepsilon_{i(t-1)}) - C(\varepsilon_{it})$. $\pi_i > 0$ if worker i participates in some KC process in time period (t-1) and decay rate is small enough. $\pi_i < 0$ if worker i does not participate in any KC process in time period (t-1) or if worker i participates in some KC process in time period (t-1) but intensity of the KC process and subsequent increased competence are is outweighed by decay rate.

As noted by proposition 2, the sum of increased knowledge by all workers of the organization participating in knowledge creation processes, $\Sigma\varepsilon_{i(t-1)}$, contribute to the core competence of the firm. The total benefit for a firm in the time period is the total cost reduction based on all workers' increased competence with corresponding intensity of those KC processes, $\pi^* = \sum_{i}^{I} \pi_i$.

In this study, we try to consider only how much money an organization can save by having workers participate in any formal KC process and consequently reducing task completion time. We do not consider the time and cost incurred when workers participate in any KC process. An optimization problem can be studied when we try to derive the best policy for an organization to having the right employees to participate in the right KC process at the right time in order to result in optimal benefit with the consideration of all possible costs.

4.4 Numerical Examples

We can use a simple numerical example to apply our model and demonstrate how an organization can benefit from having workers participate in KC processes (externalization activities). The following factors are arbitrarily set (at the beginning of time period t) to calculate the total benefit (total costs saved) for an artificial organization. Assume the following:

- Decay rate of competence (δ): 10 percent

- Highest possible gain of knowledge from any process (G_o): 0.2

- Learning rate (γ): 80 percent

- Cost per time unit for completing a task (C_o): $1,000

- Time units needed to complete a task k (T_k):

Task (k)	1	2	3	4	5
Time Units (T_k)	10	15	20	15	10

- Intensity of the KC process j (vj):

Process (j)	1	2	3
Intensity (v_j)	0.7	0.8	0.9

- Demonstrated competence of the worker i at beginning of time period t (ε_{it}):

Worker (i)	1	2	3	4	5
Competence (ε_{it})	0.75	0.8	0.85	0.8	0.6

- The process that a specific worker participates in during time period t:

Worker (i)	1	2	3	4	5
Process (j)	3	3	2	2	1

In this scenario, by applying the knowledge creation cost/benefit model, at the end of time period t, the workers' competence is derived as:

Worker (i)	1	2	3	4	5
Competence (ε_{it}) at the end of time period t with increase by participating in process and decrease by decay	0.86	0.9	0.93	0.88	0.68
Competence (ε_{it}) at the end of time period t with no participation in process and no decay	0.75	0.8	0.85	0.8	0.6

Therefore, the total cost that will be saved during time period (t+1) compared to the scenario where workers' competence will stay the same (won't decay) from period to period (after workers participated in these KC processes at time period t and all other factors remain the same) is $1,653.73. The percentage of cost that will be saved during time period (t+1) is **3.88 percent**.

If during time period t no workers actually participate in any KC process, workers' competence will be decayed as:

Worker (i)	1	2	3	4	5
Competence (ε_{it}) at the end of time period t with increase by participating process and decrease by decay	0.86	0.9	0.93	0.88	0.68
Competence (ε_{it}) at the end of time period t with no participating process but decrease by decay	0.68	0.72	0.77	0.72	0.54

The total cost that will be saved during time period t+1 compared to the scenario that workers' competence will decay from period to period (after workers participated in these KC processes at time period t and all other factors remain the same) is $3,257.98. The percentage of cost that will be saved during time period t+1 is **7.65 percent**.

In the first example, we compare a worker who participates in a knowledge creation process (and where we assume a decay rate for competence) with a worker who does not participate in the knowledge creation process and who experiences no competence decay. In the second example, we compare the same worker participating in a knowledge creation process and assuming a decay rate with the situation where the worker does not participate in the knowledge creation process and who also experiences a competence decay rate. While the second example naturally results in a greater economic benefit than does the first, the key point is that the participation in the knowledge creation process results in an economic benefit in both scenarios.

5 SUMMARY

In this paper, we have demonstrated that knowledge creation activities provide an economic benefit for the organization. Our model consists of contrasting the cost of a task in a particular time period with the cost of the task when the worker's competence has been improved by participation in a knowledge creation process. The model assumes that competence decays over time if not aided by knowledge generation or tacit knowledge transformation processes. Improvements occur by the introduction of knowledge creation processes in which the intensity factor represents the quality of the process and is gated by the learning rate of the worker.

Organizational knowledge dynamics are exceedingly complex, but while much organizational learning is unstructured, trial-and-error learning is inefficient and unpredictable. We do not suggest a deviation from Newell's (1982) basic rationality principle: *If an agent has knowledge that one of its actions will lead to one of its goals, then the agent will select that action,* but we suggest two points: first, that in a knowledge-economy, the time element for acquiring this knowledge is collapsing, and second, that organizations who step up to aggressive knowledge creation activities and processes will realize economic benefits.

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