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Organizational Learning as Catalyst to Technological Innovation*

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With rapid change and intensive competition in the global economy, the capability to capture, absorb, develop, and transfer new knowledge is a key organizational success factor. Through effective learning, companies are more likely to develop the innovation, quality, and responsiveness essential to meet the growing expectations of customers and the disruptive threats of competitors and new technologies. In the paper the role of technological innovation and its relationship to organizational learning in managing technology-based new products are examined. Several factors which can influence the rate and effectiveness of organizational learning are identified. Barriers to learning also are discussed. Finally, several managerial implications and propositions for future research on learning and technological innovation are advanced.

Key words: organizational learning, technological innovation, barriers to learning, learning sources, mobile learning

Ⅰ. Introduction

Measures of organizational success can change rapidly. Only those organizations that can adapt quickly and continuously will prosper. To adapt and innovate with increasing speed requires new ways of managerial thinking, executing, and most importantly, understanding how to learn. As management strategist, M. J. Kiernan notes:

> *Propelled by the competitive exigencies of speed, global responsiveness, and the need to innovate constantly or perish, and enabled by new information technologies, learning will become*

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the only viable alternative to corporate extinction (Schwandt and Marquardt, 2000, p. 2).

In recent years, competition has become increasingly knowledge-based (Ruggles, 1998; Amesse and Cohendet, 2001), particularly in technology-intensive industries. Iansiti and West (1997, p. 70), for example, note the following: "One targeted feature of Windows 95 operating system was that users be able to "plug and play" - that is, attach any peripheral to their computers and have the system work perfectly. To achieve that goal, each of the technologies employed in Windows 95 would have to function seamlessly with an almost unimaginable number of hardware and software combinations. The operating system would have to include literally millions of instructions and a wide range of technological approaches." Accelerating the rate of organizational learning is key to discovering better solutions to customer satisfaction and competitive advantage.

The purpose of our work is as follows. First, we examine the strategic role of technological innovation and how organizational learning facilitates technological innovation. We also identify factors influencing the rate and effectiveness of organizational learning in managing technological innovation. Second, based on a review of the literature, we propose a conceptual framework reflecting factors that impact an organization's learning regarding technological innovation as well as several outcomes from organizational learning. Finally, managerial implications and propositions for future research are suggested.

While progress has been made regarding organizational learning, more studies are required to understand the relationship between organizational learning and technological innovation. As Argyris (1999) notes, organizational learning is a competence that all organizations require. However, organizational learning should be stressed more in technology-based organizations since there is more to learn. Thus, our study is focused on organizational learning as it occurs in technological innovation. The effective management of learning can result in important competitive advantages for companies which rely on a continuous flow of new technology development projects.

Ⅱ. The Strategic Role of Technological Innovation

One of the most important, yet difficult functions organizations perform is bringing innovate new products to customers. Quinn, Baruch and Zien (1997) note that *innovation* consists of the social and managerial processes through which solutions are translated into social use in a given culture. These authors also note that technological innovation involves a novel combination of art, science, or craft to create goods

and services. Christensen (1997) further explains *technology* as the processes by which an organization transforms labor, capital, materials, and information into products and services of greater value. His concept of technology includes engineering and manufacturing as well as marketing, investment, and managerial processes. Technological innovation requires the use of new technological and/or market knowledge to offer new products or services to customers. Technological innovation is critical to the socio-economic evolution of society (Tornatzky and Fleischer, 1990).

One can easily observe the impacts new computer-based information systems and databases have had on nearly every industry (e.g., Aaker, 1998, p. 102). Information and communication technologies such as wireless sensor networks (WSN), broadband Internet, digital multimedia broadcasting (DMB) affect our lives in many beneficial ways. However, these technologies also can bring major disruptions both positive and negative. Consider this example:

> *A new computer worm, called 'SQL Slammer' hit the country Saturday, January 25, 2003, and paralyzed the country's wire and wireless Internet infrastructure for 9 hours shutting down the main servers of Internet service providers. The worm is currently proliferating internationally affecting the US and Taiwan. During the weekend, some 30 million high-speed Internet users could not use any on-line service such as Internet shopping, on-line games, public services, home banking, and Internet reservations (Source: The Chosun Newspaper, issued in Korea, January 26, 2003).*

Technological innovation also is a major factor in the renewal of organizations. Firms adopt new technologies and create new products in order to remain successful (Robbins and Coulter, 1996). Consider the following examples of successful technology-intensive companies:

- In the 1990s, for example, Intel Corporation was one of the world's most profitable companies. Intel's stock price rose at a 48% compound annual growth rate in the 1990s. In 2012 alone, it earned $53.3 billion net revenues and $11 billion net income.
- Sony, founded in 1946, recorded consolidated annual sales of over $72 billion for the fiscal year ended March 31, 2013, and employs approximately 146,300 people worldwide.
- IBM saves hundreds of millions of dollars each year in capital equipment expenditures in its microelectronics business because of a number of breakthroughs achieved by its research scientists during the 1980s (Iansiti, 1998).
- Still, the standard of innovation to which many organizations strive is that achieved by the Minnesota Mining and Manufacturing (3M). 3M is known for its successful innovations, from Scotch Tape to Post-it

Notes and has legendary status in product innovation.

The distinguishing element in each case is innovation and its application. These firms gained competitive advantage through continuous innovation. Many scholars argue that no other organizational task is more vital and demanding than the sustained management of innovation (Tushman and Nadler, 1996).

2.1 Technology strategies and organizational learning

What is needed to make business organizations more innovative? One answer is highly progressive technology strategies which rely on organizational learning. A firm's innovation strategy – its goals, timing, actions, and resource allocation efforts in using knowledge to offer new products or services – plays a crucial role in creating and using the right competencies and assets. Several strategies can be useful to organizations including offensive, defensive, imitative, dependent, traditional, and opportunist (e.g., Afuah, 1998; Crawford and Benedetto, 2010; Parker, 1978). However, there are differences in learning efforts depending on the type of innovation strategy. To successfully apply these strategies, an organization needs to be aligned with its strategy. McKee (1992, p. 243), for example, maintains that a starting point for examining an organization's learning agenda is to examine its strategy:

> *Firms with a defender-type strategy are more likely to emphasize production-oriented learning. Firms with a prospector-type strategy are more likely to emphasize innovation-oriented learning at both the product and organizational level. A mismatch of organizational strategy and learning style can be the foundation for innovation failure.*

Meyer and Utterback (1995, p. 298) note, "development of novel technologies for unfamiliar markets and latent markets requires a great degree of experimentation and learning to reduce uncertainty." The decision on which types of technologies to learn about and when to learn is closely related to the innovation strategy pursued. When firms have limited experience and resources to learn about highly innovative technologies, they often encounter difficulties in pursuing an offensive strategy. Only a few firms are able to pursue an offensive strategy by employing new, unproven technologies. While some new technologies can become 'blockbusters' they also can lead to undesirable project outcomes such as high product unit-cost, late development processes, customer dissatisfaction or market failure. On the other hand, firms with a defensive innovation strategy need to learn rapidly and innovate differently, since the "gap in market entry" and product differentiations are vital to firms employing a defensive strategy. Compared to the offensive strategy or the defensive strategy firms, those firms pursuing

imitative, traditional, or opportunistic strategies have less difficulty in learning new technologies and their application since they enter markets later and learn from the technologies already developed and diffused. There are differences in the nature of organizational learning according to the strategies a firm follows. Table 1, for example, compares 'innovative organizations' to 'imitative organizations.'

Ⅲ. Organizational Learning and Technological Innovation

Organizational learning is the capacity or processes within an organization to maintain or improve performance based on experience (Nevis, DiBella and Gould, 1995). Argyris and Schön (1978, pp. 3-4) note that "Organizational learning is the process by which organizational members

〈Table 1〉 Comparisons of Organizational Learning Behaviors: Innovators and Imitators

Comparative Dimensions	General Characteristics of Innovators	General Characteristics of Imitators
Ideas Sought	Progressive, discontinuous, nascent ideas (or technologies)	Modified, incremental ideas
State of an Idea	Probable, fuzzy, risky	Clear, safe, settled
Features of Information for Decision-Making	Qualitative, informal and approximate (Primary data)	Quantitative, formal and precise (Secondary data)
Performance	An innovative product	A imitative product (according to existing standards)
R&D Focus	Know-why	Know-where Know-how
Marketing Focus	Creating a new market; challenging existing market	Finding its survival place
Manufacturing	New processes	Efficient Processes
Culture	Reward the novel	Reward efficiency or speed to catch up
Budget	Large	Small
Management Methods	Flexible, open, & fluid	Relies on managerial controls
Techniques to Gain Knowledge	R&D, marketing research, teams, marketing, experiments, etc.	Scout, license, imitate
Types of Organizational Learning	Double-loop, or Deutero learning	Single-loop learning
Payback	Usually long-term (profiting slowly, but seen as investing in the future)	Usually short-term Immediate results are valued

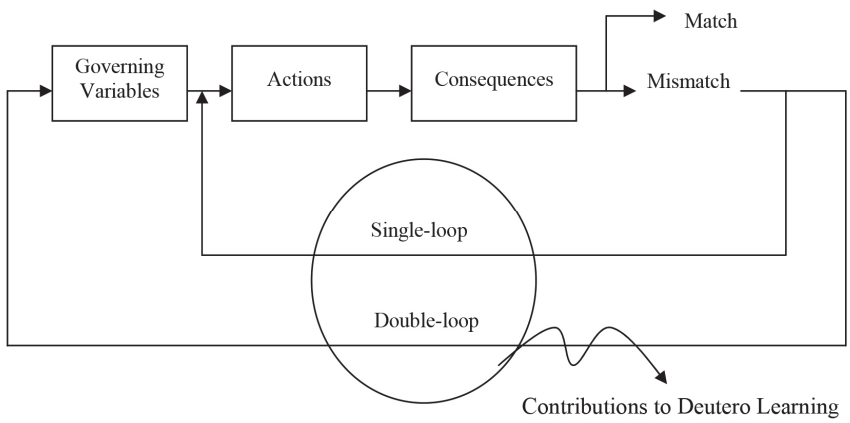
Based upon the source: J. Kim and D. Wilemon (2002), "Focusing the Fuzzy Front-End in New Product Development," *R&D Management*, 32(4), 1-11; J. Kim and D. Wilemon (2007), "The Learning Organization as Facilitator of Complex NPD Projects," *Creativity and Innovation Management Journal*, 16(2), 176-191.

detect errors or anomalies and correct them by restructuring organizational theory in use." To better understand organizational learning, the types of learning that result from detecting and correcting errors need examining. According to Argyris (1999), learning occurs under two conditions. First, learning can occur when an organization achieves what it intended -- a match between its design for action and its outcomes. Second, learning can occur when a mismatch between intentions and outcomes is identified and corrected. Whenever an error is detected and corrected without questioning or altering the underlying values of the system, this learning is considered *single-loop learning*. Whereas, *double-loop learning* occurs when mismatches are corrected by first examining and altering the governing variables and then the actions. Single-loop and double-loop learning are illustrated in Figure 1.

The efficacy of learning and the ability to change are inextricably linked. Continuous change suggests the appropriateness of single-loop learning, but the mode of learning necessary under conditions of discontinuity is double-loop learning (Douglas and Wykowski, 1999). While single-loop learning rarely leads to significant change in a firm's basic assumptions, double-loop learning can result in changing an organization's culture and strategy (Yeung, Ulich, Nason and von Glinow, 1999).

Argyris and Schön (1978) report that when an organization engages in *deutero learning*, its members learn about organizational learning and encode their results with images and maps. This phenomenon is called "learning about learning." Deutero-learning refers to an organization's or individual's learning from critical reflection on taken-for-granted assumptions (Marquardt and Reynolds, 1994). Double-loop and deutero learning are generative or creative types of organizational learning. The outcomes of organizational learning provide competitive advantages for firms in

〈Figure 1〉 Single-loop Learning, Double-loop Learning, and Deutero Learning



Modified from the source: C. Argyris (1999), *On Organizational Learning*, 2nd ed. Malden, MA: Blackwell Publishers Inc., p. 68.

the market place (Argyris, 1999).

Furthermore, McKee (1992) examines the skills needed for organizations to learn to innovate the products and services offered. In his study, three levels of organizational learning are associated with three types of innovation, for example, single-loop learning is associated with incremental product innovation; double-loop learning is associated with discontinuous product innovation; and meta-learning is associated with institutionalizing innovation in organizations. Since organizations dealing with technological innovations are likely to encounter many mismatches between desired and actual outcomes, several 'experiments' (trial & error actions) are often undertaken in order to find workable solutions to their technological objectives.

Kim (1997, p. 86) defines *technological capability* as "the ability to make effective use of technological knowledge to assimilate, use, adapt, and change existing technologies" and notes that it also enables one to create new technologies and to develop new products and processes in response to the changing economic environment. The dynamic process of acquiring technological capabilities is referred to as technological learning (Kim, 1997).

3.1 Individual learning and organizational learning

One can identify the outcomes that are frequently associated with individual, team, and organizational learning efforts (Preskill and Torres, 1999):

3.1.1 Learning Outcomes which Primarily Benefit Individuals:

- Understanding how their actions affect other areas of the organization
- Developing greater sense and sensibility of personal accountability and responsibility for organizational outcomes
- Taking greater risks
- Engaging in more coaching and consultation
- Developing more creative solutions
- Sharing work and responsibilities

3.1.2 Learning Outcomes which Primarily Benefit Teams and Organizations:

- Developing new products, services, and technologies
- Improving productivity and profits
- Increasing morale and work climate
- Experiencing less turnover
- Minimizing waste and error
- Providing more satisfying service to customers
- Creating change more quickly, with less effort and cost

To maximize all of these outcomes, organizations need to create and maintain a supportive infrastructure for learning (Preskill and

Torres, 1999). As a desired end, a learning organization is one that encourages and accelerates individual, team, and organizational learning and assists in continuously transforming their mission and actions (Bierema, 1999). Learning organizations have the potential to help all organizational members understand the critical thinking underlying what actions organizations take and why they take them. This capability helps organizations learn from both mistakes and successes. A summary of the most important features of a learning organization are noted in Table 2.

The essence of innovation and technology management lies in the ability to continually enhance an organization's knowledge base. This implies that individuals involved in innovation projects engage in a continuous learning process. These individuals transmit their learning to others and the cumulative knowledge acquired from projects can be embodied within the organization (Ayas, 1999). Iansiti (1993) notes, for example, that when it comes to transcending the product generation gap, efficiently transferring knowledge is essential. However, without fundamental changes to the entire R&D process, such as the use of integration teams to facilitate organizational learning, R&D is likely to be inefficient in undertaking product generation changes. Involving engineers in the integration of *several* product generations is critical in facilitating the transfer of valuable knowledge (Iansiti, 1993). Comparing organizational learning to individual learning, Stata (1989) ob-

〈Table 2〉 Qualities of Learning Organizations

- Capitalizes on uncertainty as an occasion for growth
- Creates new knowledge with objective information, subjective insights, symbols, and hunches
- Embraces change
- Encourages accountability at the lowest levels
- Encourages managers to be coaches, mentors, and facilitators of learning
- Has a culture of feedback and disclosure
- Has shared organization wide vision, purpose, and values
- Has decentralized decision making and employee empowerment
- Has leaders who model calculated risk taking and experimentation
- Has systems for sharing learning and using it in the business
- Is customer driven
- Is involved in its community
- Links employees' self-development to the development of the organization as a whole
- Provides frequent opportunities to learn from experiences
- Uses cross-functional work teams
- Views the organization as a living, growing organism
- Views the unexpected as an opportunity to learn

Source: M. Marquardt and A. Reynolds (1994), *Global Learning Organization: Gaining Competitive Advantage through Continuous Learning*, New York: Irwin Professional Publishing, p. 23.

serves that organizational learning occurs through shared insights, knowledge, and mental models. Further, learning builds on past knowledge and experience, which depends on an organization's capabilities for capturing and retaining knowledge.

3.2 Mobile learning and its importance to organizational learning

As mobile devices are increasingly prevalent and converging into individual information centers such as smart cell phones, tablet PCs, or notebook PCs, mobile learning becomes an important learning channel for organizations. Thus, it is important for organizations to recognize how state-of-the-art mobile technologies can enhance its technological and competitive position. Mobile technologies facilitate organizational learning via: constant and 'just-in-time' connectivity, richness of information available from the internet, fast diffusion of information, information storing abilities, as well as rapid information gathering for problem solving. However, they also can produce challenges to organizational learning such as, security problems, requiring information filtering systems to prevent information overload, and other challenges.

Though research in the application of mobile learning is still emerging, it has become an indispensable technology and is bringing about changes in the way organizations use knowledge. Moreover, as Zakaria *et al.* (2004) note, information and communication technologies are not just simple tools, instead they need to be aligned with team design and the processes of collaborating with others. Mobile technologies are proving their value to organization learning.

Ⅳ. Enhancing Learning Opportunities in Technology-Based Organizations

Finger and Brand (1999) note that individual capacity to learn corresponds with an individual's ability and competence. However, organizational capacity is facilitated by both individual and collective capacities (organizational capacities) to learn.

The outcomes and the usefulness of learning depend heavily on the content and awareness of what is learned (Huysman, 1999). Von Hippel *et al.* (1999) note that what distinguishes companies is the kind of information they collect and from whom they collect it. Thus, the ability to identify information about new technologies is critical. Forecasting new technologies and assessing their impacts including the cross-impact of one technology on another is important in selecting which technology to pursue (Aaker, 1998, pp.118-119).

Venues of learning include manufacturing processes, management information systems, marketing, R&D, supply chain management, team processes, productivity improvements, customer

relationships/satisfaction, outsourcing processes, management information systems, managerial processes, strategic alliances, etc. (Crawford and Benedetto, 2010, pp. 533-538). The sources of organizational learning can be categorized into internal, external, and global sources (see Table 3). Organizational learning can occur in each functional group as well as across an entire

〈Table 3〉 Selected Examples of Learning Sources

Sources of Learning	Learning Areas	Examples
Internal Sources	R&D/ NPD Processes	Technological Innovations Technological "Roadmaps" Experiments Technology Forecasting
	Marketing	Strategies Execution Marketing Mix
	Manufacturing	Suppliers Prototyping New Methods/Processes New Materials Quality Initiatives Outsourcing
	Human resource management	New Employees Incentive Systems Teaming Cross-Functional Integration Training
External Sources	Market participants	Customers Lead-Users Market Tests Competitors Intermediaries
	Alliances	Joint Ventures Direct Investments Licensing
	Developments within and across other Industries	Improvements in Telecommunications Internet Improvements in Technology
	Universities	University - Industry Collaboration
	Consultants	New Methods/Applications
	Inventors	Technological Innovations
Global Sources	Global competitors	Global Products Global Raw Materials
	Global networks	Global Telecommunications
	Global teams	Cultural Diversity

organization. It is important to note that 'venue for obtaining existing knowledge' differs from 'venue for developing new knowledge.' Im and Workman (2004) found that creative ideas in new products and related marketing programs mediated the relationship between market orientation and new product success and that the meaningfulness dimension, rather than the novelty dimension, of creativity is of greater importance in explaining the link between market orientation and new product success. Their findings also indicate that customer orientation can be detrimental to the generation of novel perspectives for new products in high-technology firms. They also maintained that mangers should evaluate trade-offs between the positive and negative effects of market orientation on creativity.

All learning has the potential for interacting with each other. Technological organizations which demonstrate high capacities for integrating their learning are the more likely to achieve high performances.

4.1 Factors influencing organizational learning

In order to accelerate and improve organizational learning, the factors influencing organizational learning need to be identified. Garvin (1993), for example, notes that learning organizations are skilled in systematic problem-solving, experimentation with new approaches, learning from experience and past history, learning from the best practices, and transferring knowledge quickly and efficiently throughout the organization. Nonaka and Takeuchi (1995) suggest several characteristics of knowledge-creating companies: expressing the inexpressible by using metaphors and analogies; disseminating knowledge by sharing an individual's personal knowledge with others; and acquiring new knowledge in the midst of ambiguity and redundancy. Relating to "redundancy," these authors note that a product development team can be divided into competing subgroups that develop different approaches to the same project and then assess the advantages and disadvantages of their alternative proposals. From this procedure, the team eventually develops a desirable approach and shares a common understanding of it. Kim (1997, pp. 92-94) illustrates the dual approach used in the development of the 256K DRAM and the 1M DRAM at Samsung. Calantone *et al.* (2002) notes that a learning orientation affects firm innovativeness, which in turn influences performance. In their study, "learning orientation" is a higher- order construct composed of four components, such as commitment to learning, shared vision, open-mindedness, and intraorganizational knowledge sharing.

4.2 Major barriers to learning in technology-based firms

Schein (1996) proposes several reasons for learning failures. He notes that there are three

different major occupational cultures in most organizations – the "operator," "engineering," and "executive" cultures and that a lack of alignment among these three groups hinders learning. There are also personal and organizational factors that inhibit learning. Examples of individual barriers to learning are a lack of self-esteem, low expectations in the pursuit of learning goals, the inability to communicate, one's physical condition, and the level of stress experienced. Additionally, an organization's structure, culture, and communication and feedback systems can be major barriers to learning (Antonacopoulou, 1999). These factors seriously limit an organization's ability to respond to its environment. In addition, they result in a loss of competitiveness in high-growth, lucrative markets, a loss of image, self-imposed censorship of ideas, and the attrition of good people (Vandermerwe, 1987). Based on previous research, we classify major barriers into the following categories: individual, leadership, organizational, and situational blocks. Several examples are noted in Table 4.

〈Table 4〉 Majors Barriers to Learning in Technology-Based Firms

Barriers to Learning	Examples
Individual Blocks	• Intellectual mental capability (Antonacopoulou, 1999) • Lack of self-confidence • Lack of control over one's own work (Amabile, 1988) • Resistance to change • Lack of communication abilities • Lack of knowledge/experiences
Leadership Blocks	• Lack of vision • Inappropriate leadership style • Not recognizing and valuing learning
Organizational Blocks	• Inappropriate reward systems (Amabile, 1988) • Lack of a clear strategy • Inappropriate organizational structures • Insufficient empowerment • Lack of communication • Unclear functional group roles • Lack of diversity • Lack of a creative culture • Listening to current customers (Christensen, 1997) • Conventional wisdom • Inability to recognize emerging technologies • Over reliance on past success formulas • Functional dominance, e.g., R&D • Unwillingness to challenge existing mental models
Situational Blocks	• Insufficient time and resources (Amabile, 1988) • Satisfaction with status quo • Lack of incentives to change

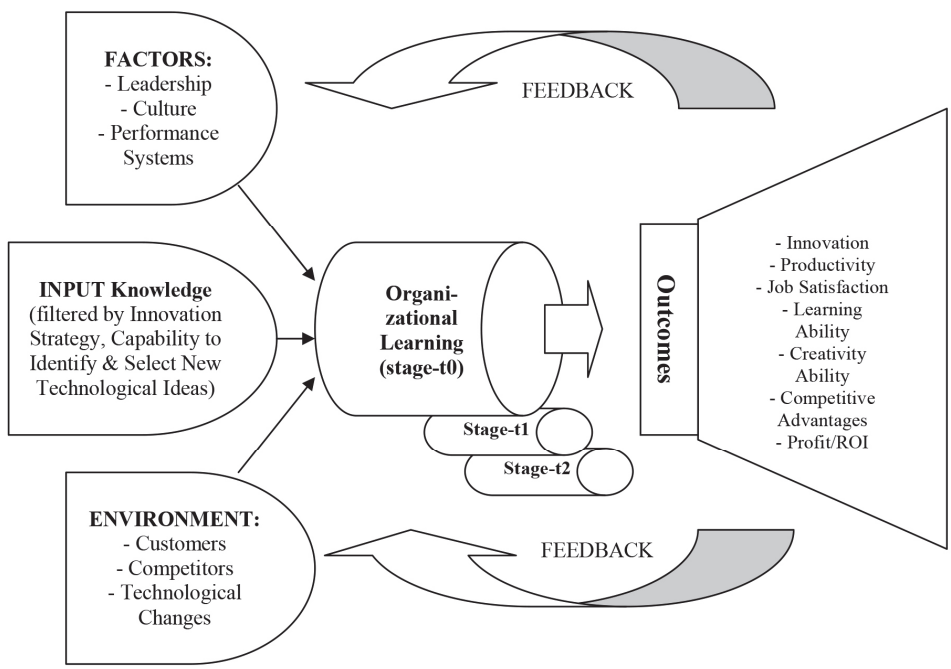
Disseminating knowledge quickly and efficiently throughout the organization is consistently emphasized as a key to building a learning organization. Research in product innovation has evolved from learning in a single NPD project, to inter-project learning, to learning in the wider product innovation processes (Boer *et al.*, 2001; Gieskes and Hyland, 2003). Thus, it is necessary to gain insight into factors that hinder learning in these different learning venues. Gieskes and Hyland (2003) reported on learning barriers identified by product managers in over 70 companies and noted that the majority of the barriers can be labeled as organizational defensive routines leading to a chain of behaviors; lack of resources leads to under appreciation of the value of useful information, absence of informed choice and lack of personal responsibility.

4.3 A comprehensive framework of organizational learning process

The integration of several learning capacities creates an organization's capacity to continuously learn. Focusing on only one or two aspects of learning limits an organization's potential. We suggest an organizational learning framework for technological innovations in Figure 2.

Figure 2 reveals that there are many forces shaping organizational learning. As noted, various factors such as culture, performance systems and leadership influence organizational

〈Figure 2〉 A Framework of Organizational Learning Process



learning. Moreover, what to learn (: Input Knowledge) and under what circumstances (: Environment) can affect organizational learning. The results of effective learning can lead to innovation, productivity, and competitive advantage. In addition, the feedback from performance can affect the learning process. Figure 2 also illustrates the dynamic or cumulative features of organizational learning. A mastery of technological learning at one stage provides a platform for the subsequent technological learning.

V. Managerial and Theoretical Implications

To perform successfully in highly competitive global markets, the ability to *innovate* is imperative, especially for technology-based companies, as well as for many firms operating in emerging and transition economies. Managing innovation requires the ability to continually build the underlying organizational knowledge base via effective *organizational learning*. Organizational learning is related to discovering new and better solutions and linking them to customer satisfaction and competitive advantages. The learning outcomes, which result from dealing with complex, innovative tasks, technologies, markets, and other organizations, are more likely to provide competitive advantages. Understanding organizational learning and identifying its influencing factors and their consequences are important. However, it is also important to have systems for sharing learning and using it to accomplish the organization's objectives. The following are several managerial approaches for achieving a learning organization.

5.1 Developing a learning culture

Organizational culture is created by the shared norms and values within a firm. Organizational members' beliefs regarding a product and/or technological innovation in promoting corporate objectives is a shared value (e.g., Dwyer and Mellor, 1991). The significance of the context in which learning takes place is receiving increased attention. A basic requirement is a culture that encourages, facilitates, and rewards learning (Finger and Brand, 1999). Stata (1989) notes that the values and culture of an organization have a significant impact on individuals and the collective learning processes and on how effectively a company can adapt and change. For example, the GE slogan ("finding a better way everyday") and the Apple slogan ("think different") were used to foster a learning culture. This translates into a set of core values that directly encourages learning and innovation (Finger and Brand, 1999; Yeung, Ulrich, Nason and von Glinow, 1999).

5.2 Achieving competence through staffing and development

Here, the emphasis is on the extent to which individuals, teams, and organizations have capacities for learning and represent the knowledge, skills, and abilities of individuals or teams within an organization. In that frame, specific actions managers might take to build learning capabilities include:

- Hiring and/or promoting people who have demonstrated a capacity to learn (Quinn, Anderson and Finkelstein, 1996): Adding people with the capacity to learn is positively related to the learning capability of a team, but it does not guarantee high team performance. Specific qualities, e.g., selfishness, may have negative effect on previous cooperative or shared climate in the team. Moreover, a new team member's ability cannot be fully utilized by a team leader who cannot manage creative individuals.
- Instituting job rotations and assignments across divisions (Yeung, Ulrich, Nason and von Glinow, 1999)
- Removing or reassigning nonlearners
- Creating training programs to share best practices
- Sponsoring educational programs: Botkin's (1985) innovation model starts by assuming a level of creativity and then focuses on four issues: education, management style, research and development, and capital costs. He stresses the importance of education since technology is fast-paced and organizations are highly complex.

5.3 Establishing innovation reward systems

To encourage performance, it is important to provide rewards that people value in a timely, fair manner (Cascio, 1998). Since people generally act out of self-interest, building learning capability and setting reward systems for specific learning behaviors can be helpful. Rewards need not be limited to tangible or financial terms. Most people value personal accolades, particularly if they immediately follow positive action (Crawford and Benedetto, 2010). Quinn, Anderson and Finkelstein (1996, p. 72) note, "Highly motivated and creative groups often outperform groups with greater physical or financial resources." The following practices related to rewards can prove useful (e.g., Yeung, Ulrich, Nason and von Glinow, 1999):

- Changing performance appraisals to include learning objectives, actions, and outcomes
- Rewarding useful postmortems of mistakes and successes
- Encouraging and rewarding experimentation
- Integrating bonus/incentive systems with learning objectives and outcomes

5.4 Building organizational structures and communication processes

The structural capacity to learn corresponds to the characteristics of an organization which favors individual and collective learning (Finger and Brand, 1999). Learning and its contribution to product innovation is influenced by the organization's structure and its communication practices (Ayas, 1999). The organization's structure, decision-making process, and information systems need to be designed to encourage high-impact ideas which support the company's mission. It is important to note that innovative ideas often involve a high degree of technology and can be slow-movers, they need conscious, effective promotion in order to overcome resistance (Vandermerwe, 1987).

It is useful to identify the previous experiences of the organization that are relevant to current projects, as well as to integrate new information and experiences into the organization's knowledge base (Iansiti and MacCormack, 1997). The *Intranet*, for example, has clearly allowed organizations to share knowledge more effectively. Empowerment helps create a successful learning environment. It enables individuals and teams to set their own goals, make decisions, and solve problems within their sphere of responsibility (Crawford and Benedetto, 2010; Moorhead and Griffin, 1995). If employees are offered the ability to achieve responsibility, recognition, and opportunity, they are more likely to perform and learn at higher levels. Stata (1989) found that the best way to introduce knowledge and modify behavior is by working with small teams that have the power and resources to enact change.

5.5 Organizing effective work processes and systems

How work is accomplished can facilitate learning. Capacities resulting from the organization of work imply that the production processes are organized so that individual and collective learning is valued and not impeded. Even more important, designing and structuring work systems can continuously reinforce an organization's capacity for change. The following actions can be useful:

- Building flexible, current information systems
- Establishing physical settings that encourage idea sharing
- Participating in team or cross-functional assignments
- Developing activities which foster learning

5.6 Appointing leaders who promote learning and are capable of learning

Leader behavior is another important element of an organization's learning capacity. Through their behavior, management style, reward & recognition systems, as well as coaching and mentoring, leaders have a significant influence

on individual and collective learning (Finger and Brand, 1999). No other role in organizations has received more interest than that of the leader (Schwandt and Marquardt, 2000). Leaders are central to building learning capability as an organization's culture often reflects the personality of its leaders; consider GE, Samsung, Apple, Microsoft, Motorola, HP, and Cisco Systems. Leaders engage in numerous activities which can model effective learning.

In summary, the theoretical implications that can be derived from our work follows:

- Behavioral and structural factors such as culture, capabilities, and leadership can influence organizational learning. Understanding these factors and their relationships can be helpful in creating a learning organization.
- There are differences in learning efforts depending on the type of innovation strategy. In order to successfully apply these strategies, an organization and its structures need to be aligned with its strategy.
- Selecting what, where and how to learn are critical in maximizing the efforts invested in learning. However, the priority and the weights are different according to types of firms, products/services, competitive intensity, etc. Moreover, these considerations often need depending on the organization's environment.
- Accelerating as well as improving organizational learning is critical considering the speed and competition advantages which result.

Ⅵ. Limitations and Future Research Propositions

Our study deals with organizational learning in technology-based firms. Our purpose is to provide a cornerstone helpful in investigating more specific issues regarding the relationship between organizational learning and technological innovation. However, the suggestions in our study are not supported by empirical data and appropriate cases. Moreover, there are missing factors which may influence the organizational learning process. However, the main contributions of our paper are the reviews of numerous studies on organizational learning in technological innovation and the development of an organizational learning framework based on extant literature.

In the following, we develop several questions and propositions needing further study. For example:

6.1 How can organizational learning be facilitated?

Calantone *et al.* (2002) suggest that research is needed to identify both the antecedents and the consequences of learning. Relating to this issue, the following propositions are advanced:

- Identifying specific qualities of team leaders, e.g. risk-taking, job experiences, team development skills, etc, are related to promoting a learning climate which encourages and accelerates individual, team, and organizational learning.
- Valuing learning from mistakes and failures is positively related to creating a learning climate which encourages and accelerates individual, team, and organizational learning.
- Learning capability gaps among functional groups are negatively related with an organization's learning capacity.
- Forming a team with people having the capacity and willingness to experiment is positively related to a development team's learning ability.
- Creating dedicated teams that are more likely to achieve higher levels of organizational learning than functional or matrix teams.
- Learning develops from a combination of learning capability and learning motive. Learning capability is related with the degree of experiences and individual capability, on the other hand learning motive is related with high motivation and a sense of urgency.
- Working with alliances and partners or adopting a new IT system is likely to facilitate organizational learning due to the challenges encountered.

6.2 What are the major links between organizational learning and NPD performance?

Organizational learning appears critical to NPD performance. However, how organizational learning impacts NPD performance needs further study. The propositions noted below can help understand this relationship:

- The impact, value, and types of organizational learning can vary according to the specific NPD phase.
- The ability to transfer knowledge/information is closely correlated to the capacity to innovate. Building capability in both areas is critical to learning organizations.
- Organizational learning is positively related to NPD acceleration.
- There are differences in organizational learning orientation according to firm circumstances. For example, the ability to innovate is positively related to an organization's learning orientation.

6.3 What factors moderate organizational learning?

Since the relationships between organizational learning and firm performance are contingent on different situations, it is important to identify meaningful moderating variables and to find their potential moderating effects. We advance

these propositions:

- The greater the technological complexity involved in NPD, the greater the organizational learning that occurs and the higher the rate (speed) of learning.
- Team structures, information system capabilities, organizational culture (e.g., resistance to/acceptance of learning), and learning capabilities may moderate the relationship between organizational learning and firm performance.

6.4 What subjects need further study regarding the role of mobile learning?

To maximize mobile learning, organizations need to understand and manage the process of mobile learning. We therefore advance the following research propositions:

- What types of organizational structure, culture, and leadership can enhance mobile learning?
- How can mobile learning be helpful to globalizing businesses?
- How can mobile learning help transcend cultural barriers?
- What managerial challenges might develop due to mobile learning? What organizational behaviors will be changed by mobile life: Trust, ethical, or intellectual property rights issues?
- What are the tradeoffs between security and knowledge sharing with others?
- What methodologies, mobile tools and devices are effective for learning in the mobile organization? What are emerging technologies for mobile learning and how might they influence the design of organizations?

Sustained management of technological innovations is vital for organizations. Organizational learning will continue to play an important role in the process of technological innovation. In order to maximize performances, additional study on the relationship between technological innovation and organizational learning is needed.

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