ON THE DISTINCTION BETWEEN KNOW-HOW, KNOW-WHY, AND KNOW-WHAT

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ABSTRACT

Although the term know-how has been widely used to represent knowledge, it is but one component of the intellectual capital involved in the design, manufacture, and use of technological systems. There are at least two other components of knowledge. These are know-why and know-what. Know-why represents an understanding of the principles underlying phenomena. Know-what represents an appreciation of the kinds of phenomena worth pursuing. Know-how represents an understanding of the generative processes that constitute phenomena. I explore the properties of these three knowledge components and the interrelationships among them. I suggest that firms are now operating in an environment where there is an increasing need to synchronize the creation and deployment of these components. I discuss technological and organizational designs that might accomplish such a synchronization.
It is a source of consternation to my wife that, despite my engineering education, I am all thumbs when it comes to fixing anything. Just recently she asked me to fix my son’s toy car. Tapping into my “vast” engineering knowledge, and with my daughter watching, I valiantly tried to do something. Alas, my efforts came to naught. My wife and daughter both went away further questioning my competence as an engineer.

I have tried to explain to my wife that engineering knowledge comes in different forms and that knowledge of why something works does not necessarily translate to a knowledge of how it is put together. By the same token, I have argued that an expert mechanic may have little knowledge of the principles of engine design that I possess. My wife has dismissed all these explanations as being nothing more than idle prattle from an under-worked academic. I fear that nothing I say will ever convince her that my engineering days were not truly wasted. It is to redeem myself, at least in the eyes of my children, that I have taken it upon myself to write this paper.

Besides trying to communicate with my family, I have another important reason for writing this paper. I see the term “knowledge” being increasingly used by both practitioners and scholars in the field of management. Details abound on how it is created and nurtured, how it diffuses, and how it must be protected. By some accounts knowledge appears to be the key strategic asset of the twenty-first century. Indeed, Alcoa’s CEO, Paul O’Neil suggests that we are witnessing nothing short of another industrial revolution (one that Ralph Stayer, CEO of Johnsonville Foods and his consulting partner James Belasco call “intellectual capitalism”) where artisans are “using their heads and not their hands” (Arthur, 1991). In a similar vein, a correspondent for Business Week (1992) states that “competitive advantage no longer belongs to the biggest or those blessed with abundant natural resources or the most capital. In the global economy, knowledge is king.”

All this talk of knowledge begs a simple question: what exactly is it? I opened my trusted Webster’s dictionary and found the following definitions: “the fact or condition of knowing something with familiarity gained through experience or association”; “acquaintance with or understanding of a science, art or technique”; “the fact or condition of being aware of something” (Webster’s, 1991). Clearly, knowledge has a range of meanings.

Despite this range, we frequently use the term “know-how” when we refer to knowledge. Such a reduction may perhaps be acceptable for colloquial purposes. However, the pernicious side of such a procrustean transformation becomes obvious when we try to manage knowledge as a strategic asset and find that the properties associated with know-how do not readily transfer to its other components.

A similar concern led Winter (1987, p. 170) to write a paper on knowledge and competence as strategic assets. Alluding to terms such as knowledge, competence, and skill, he wrote: “When we use such terms, we hardly ever know precisely what we are talking about, and there is sometimes a nagging concern that we are too far from the complex details to be making sense at all.” Consequently, Winter offered
a whole taxonomy of dimensions that "clarify the conceptual issues surrounding knowledge and competence as strategic assets."

My work both differs and builds upon Winter's in that it examines the constituent components of knowledge as compared to its dimensions. Specifically, besides know-how, I explore two additional components of knowledge: know-why and know-what. My purpose in making this distinction is to highlight differences in the properties of each of these components, and thereby, make a case that each of these components must be managed somewhat differently.

Toward this end, I address several questions that are relevant to the management of these components. For instance: How do firms acquire these knowledge components and where do they reside? If we conceptualize each component of knowledge as a stock, then, the underlying learning processes that create them represent flows (Karnoe, 1995; Starbuck, 1992). An appreciation of these learning processes raises two other questions: How rapidly can each knowledge component be acquired, and, how rapidly does each component decay? Another question key to the management of knowledge as a strategic asset is: How easily are these knowledge components transferable within and across firm boundaries?

As I began addressing these questions, I quickly realized that it was well beyond my reach to do justice to all the issues pertaining to knowledge and learning. I also realized the fragility of my own understanding of knowledge. Occasionally, I would find clarity at one level of analysis only to find it blur at another.\(^1\) For all these reasons I have taken refuge in ambiguity by not offering an in-depth discussion on any one issue. Rather than being a definitive statement, I regard my paper as one that raises issues that are in need of further research and consideration in practice. I encourage readers to treat all the statements in my paper as being tentative hypotheses open to discussion and verification.

I have organized the paper as follows. First, I provide a brief introduction to the different components of knowledge and explore their underlying properties. Then, I review different models of technological change and examine the emphasis each places on these knowledge components and the interrelationships among them. This review sets the stage for a discussion of how these components can be managed in a holistic manner. In the concluding section I offer some implications for research and practice.

**COMPONENTS OF KNOWLEDGE**

Knowledge represents an understanding of phenomena. In the context of technological systems, knowledge represents an understanding of the principles that underlie their functioning, processes employed to create them, and the uses that these technological systems serve. These three facets represent know-why, know-how, and know-what respectively.\(^2\)
For instance, consider a computer that comprises many components that together provide utility to users. Know-why represents an understanding of the principles underlying the construction of each component and the interactions between them. Know-how represents an understanding of procedures required to manufacture each component and an understanding of how the components should be put together to perform as a system. Know-what represents an understanding of the specific system configurations that different customer groups may want and the different uses they may put these systems to.

We often use the term “know-how” to capture all three components of knowledge. This is understandable given the technological milieu of the twentieth century. Specifically, part of “scientific management” can be viewed as an effort to systematize and codify the know-how required to produce complex technological systems by using time and motion studies (Zuboff, 1984). Such a rationalization enabled the mass production of technological systems and served as the basis for the creation of wealth for the U.S. economy in general and its firms in particular.

The creation and exploitation of know-why is another important part of the industrial landscape of this century (Schumpeter, 1942; Nelson, 1959). Indeed, an important role of R&D laboratories has been to generate knowledge of the principles that underlie the operation of technological systems. Advances in our understandings of these principles have often established the foundation on which new products and processes have been developed for commercial purposes (Comroe & Dripps, 1976).

Although know-how and know-why are both important components of knowledge, it is only recently that there have been attempts to make a distinction between them (Zuboff, 1984; Kogut & Zander, 1992; Bohn, 1994). Less explored in the management literature, but an important theme in the marketing and technology literatures, is a third component of knowledge—know-what. Although this component has always been important, it is becoming all the more so in contemporary environments characterized by rapid change and mass customization where customers are increasingly exercising their choices.

Know-how

Know-how is created by a process of “learning-by-doing” (Arrow, 1962; Dutton & Thomas, 1985; Argote & Epple, 1990). Learning-by-doing is a process whereby knowledge about how to perform a task accumulates with experience over time. Prior experience often dictates future learning possibilities, thereby rendering this process a cumulative and path-dependent phenomenon (Arthur, 1988; David, 1985; Levitt & March, 1988).

Once created, such knowledge may reside in different “storage bins” (Walsh & Ungson, 1991). These bins include individuals, organizational routines (Nelson & Winter, 1982), and manufacturing processes (Argote, 1995). Some aspects of know-how are articulable through time and motion studies and through stories that
form part of the organizational culture (Levitt & March, 1988; Brown & Dugid, 1991). Other aspects of know-how, though, may remain tacit (Polanyi, 1967; Nonaka, 1994; Spender, 1993) or invisible (Itami, 1987).

Time and motion studies that comprise part of the scientific management movement have made it easier and faster for individuals to acquire such production know-how. Organizational routines and manufacturing practices, however, may take a longer time to create than it might take to create individual know-how. In both instances, however, unit labor costs decreases as the cumulative output increases through a "practice-makes-perfect" principle (Dutton & Thomas, 1985; Argote & Epple, 1991).

The cumulative reduction in manufacturing costs that accrues from such experience represent "learning curves." These learning curves are often characterized in terms of a "progress ratio." For instance, if each doubling of cumulative output leads to a 20 percent reduction in unit costs, then the progress ratio is 80. As this example illustrates, diminishing returns set in from learning-by-doing as the accumulated stock of know-how asymptotically reaches some limit.

The ease with which know-how can be transferred depends on where it resides and whether it is being transferred within a firm or between firms. In general, it is much more difficult to transfer organizational routines than it is to transfer manufacturing practices (part of which might be documented) and manufacturing know-how resident in people. Moreover, the greater the difference in the contexts of the units between which know-how is being transferred, the more difficult the transfer. Consequently, it is more difficult to transfer know-how between firms than within a firm. It is most difficult to transfer know-how from one firm to the other if know-how is protected as a trade secret. Under these circumstances, know-how can be a basis for sustainable competitive advantage.

Argote and her colleagues have documented several instances of know-how decay in sites where production activities were disrupted (e.g. Argote, Beckman, & Epple, 1990). However, it appears that this outcome may be contingent upon the extent to which know-how has been institutionalized in the form of organizational routines and manufacturing practices. To the extent that know-how is not institutionalized, any disruption of production activities, including turnover of people, is likely to result in the decay of know-how (Devadas & Argote, 1992). From these observations Argote and her colleagues came to the conclusion that know-how may decay at a slower rate if it is embedded in organizational routines and manufacturing practices.

However, such embedded know-how can be too enduring (see Burgelman, 1994). Because they are often so deeply ingrained, embedded know-how may be difficult to change even when circumstances warrant them, creating what have been labeled as competency traps (Levitt & March, 1988) or core rigidities (Leonard-Barton, 1992). The recent business process reengineering phenomenon might be viewed as one attempt to address this problem (Hammer & Champy, 1993).
Know-why

A different type of learning underlies the creation of know-why. Dutton and Thomas (1985) label this process "learning-by-studying." Learning-by-studying involves controlled experimentation and simulation to understand the principles and theories underlying the functioning of a technological system.

One view of this process is that the accumulation of knowledge is cumulative within the confines of an overall "paradigm" (Kuhn, 1970; Constant, 1980; Rosenberg, 1982; Laudan, 1984). Prior knowledge shapes the problems that we address, the instrumentation that we use, and the solutions that we may find (Garud & Rappa, 1995). Consequently, the accumulation of know-why, too, is path dependent.

It might appear that know-why is generated during moments of inspiration and creativity occurs instantaneously and in a random fashion. However, these "eureka" moments result from a cumulative syntheses of insights that build up in an evolutionary fashion (Usher, 1954). For such a process to unfold, first, prior knowledge is essential to assimilate new knowledge (Cohen & Levinthal, 1990). Second, for a process of cumulative synthesis to unfold it is important to "bi-associate"—that is associate ideas from unrelated fields to create a totally new one (Koestler, 1964; Garud, Nayyar, & Shapira, 1997b).

Know-why can exhibit increasing returns (Nelson, 1959; Arthur, 1991). These increasing returns accrue when knowledge in different scientific and technological fields coalesce to create new knowledge through a process of cumulative synthesis (Usher, 1954). Increasing positive returns also accrue when an understanding of one phenomenon opens up new avenues of exploration (Adler, 1989b). In other words, there is a "multiplication" effect from both the fusion of knowledge streams, and from the new paths of inquiry that know-why at one level of analysis opens up at another.5

Individuals are proactive in seeking know-why in technological settings.6 A large portion of such know-why can be, and is, documented for future reference in the form of laboratory notes and other technological documents. Particularly in the case of scientific findings, know-why is published in journals and disseminated to others in seminars. Indeed, many have observed that because scientific knowledge often diffuses rapidly, firms may underinvest in its creation (Nelson, 1959; Arrow, 1962). Consequently, a case has been made for government funding and sponsorship for the creation of such "leaky" know-why (Utterback, 1974; Stobaugh, 1985).

A way to induce private sector to produce such know-why is to provide intellectual property protection. However, despite intellectual property protection in the form of patents, know-why generally leaks out, albeit at a slower pace than if it were not protected at all (Levin, Kleverick, Nelson, & Winter, 1987; Mansfield, 1988). It is for this reason that several firms might maintain knowledge of how to accomplish a task as a trade secret rather than rely on their know-why. Alternatively, in cases where it may not be possible to protect intellectual property
through trade secrets, firms will have to continually innovate to keep abreast of competition even as its intellectual know-how and know-why leak out (Garud, 1994).

The “nomological net” of causal relationships that constitute such scientific and technological know-why get congealed into an overall “paradigm” that is often difficult to dislodge (Dosi, 1982; Kuhn, 1970). Indeed, as I have suggested elsewhere, researchers’ causal beliefs, their evaluation routines and the technological artifacts they champion together form a self-reinforcing system that “locks” researchers into a trajectory (Garud & Rappa, 1994). The strategic implication of such “cognitive stickiness” is most apparent when adherence to these trajectories renders researchers blind to alternative approaches (Weick, 1979).

**Know-what**

“Learning-by-using” is an important way by which know-what is generated (Rosenberg, 1982; von Hippel, 1988; Karnoe, 1993). For technological systems, such learning is important because customers invariably use technological systems in ways different from how they were designed or produced. Learning occurs through interactions between vendors and customers. Customers use a system and provide feedback to vendors on the desirable system configuration and range of possible uses. Based on this feedback, vendors can modify system configuration.

Because know-what is generated through interactions between producers and users, this knowledge is not just resident at either of these “nodes” but is created and situated at the nexus of the vendor-buyer relationship (Glynn, Milliken, & Lant, 1994; Brown & Duguid, 1991). Customer preferences unfold as they use products offered by the vendor. Vendors capabilities evolve to meet customers’ unfolding preferences. The melding of these two processes results in an overall dynamic process of product development that has been labeled rapid prototyping.

For most part of the twentieth century, such learning has been “episodic” (Tyre & Orlikowski, 1995), with vendors seeking feedback from “lead users” (von Hippel, 1984) during the early stages of technology emergence and then offering customers products manufactured to a set of specifications that conform to the dominant standard (Utterback & Abernathy, 1975; Tushman & Anderson, 1986; Tushman & Rosenkopf, 1992). More recently, however, customer preferences appear to be changing continually in many frontier fields such as computers and electronics. In these environments, rather than being episodic, learning-by-using has become a continual activity.

Indeed, the more rapidly an environment changes, the more quickly does knowledge of what customers want become obsolete (Day, 1994; Kenney, 1996). Consequently, in rapidly changing environments know-what acquisition is neither cumulative, nor is it path-dependent. In the extreme, as in the case of many service goods, knowledge of customers needs is transitory, with learning occurring on each occasion at the point of sale and use. Thus, in rapidly changing environments
learning of what customers want has to be a continual activity, but knowledge of what customers want may not necessarily accumulate.

Even in these environments, however, it is possible to preserve knowledge of system features that customers may want by modularizing the technological system along functional lines. Modularity compartmentalizes know-what thereby increasing the ease with which users and vendors can substitute certain system components while retaining all the others. Increasing returns set in as the combination of system configurations increases with modularity. However, after a while, any further modularity increases system complexity (Baldwin & Clark, 1994) and therefore results in a decrease in economies. We have used the term “economies of substitution” to allude to these returns in the creation of know-what from modularity (Garud & Kumaraswamy, 1993, 1995a).

As we enter an environment where customers want mass-customized systems, it is becoming more difficult to transfer knowledge of what one group of customers may want to another. Difficulties in transferring knowledge of what one customer wants to another is also true of the sale of complex products that involve ongoing vendor-supplier relationships. Often, because a knowledge of what is required is embedded in the relationship itself, such know-what is not easily transferable to rival firms either. However, to the extent that a firm is dealing with commodity products, one firm’s knowledge about customers’ wants can be fairly transparent to rivals. In these cases, such knowledge by itself cannot be the basis for sustained competitive advantage for any firm.

Summary

So far, I have introduced three components of knowledge and have explored some of their underlying properties. To recapitulate, each component is acquired through different means—know-how through a process of learning-by-doing, know-why through a process of learning-by-studying, and know-what through a process of learning-by-using. Each component exhibits different economies—know-how demonstrating decreasing returns to scale, know-why increasing returns to scope, and know-what increasing returns to substitution. Once created, these knowledge components reside in different “storage bins.” Know-how resides in individuals, organizational routines, and manufacturing practices. Some parts of know-how can be articulated and documented whereas other parts may remain tacit. Know-why resides in individuals and is frequently articulated in documents. Know-what often resides at the nexus of the relationship between vendors and customers. There usually is an attempt to document such knowledge in marketing and sales reports.

These various bases for learning and storage result in differential rates of acquisition, decay, and ease of transfer. Some portions of know-how and know-why may take longer to acquire and decay in comparison to know-what that is becoming obsolete more rapidly in contemporary environments. Knowledge embedded
in organizational routines (organizational know-how) and in vendor-customer relationships (relationship specific know-what) are more difficult to transfer as compared to knowledge that is not embedded within an organizational context (some portions of stand-alone know-why). Consequently, embedded knowledge can serve as an enduring source of sustainable advantage for firms.

Clearly, these differential properties imply that each of these components of knowledge be managed somewhat differently from the other. However, to truly manage knowledge as a strategic asset, it is important to manage not just its constituents, but all three components together as a system (Senge, 1990). Bringing all the three elements together is key to harnessing associated synergies and overcoming the myopia that inevitably develops if we focus on one element at the exclusion of the other. Managing all three components together as a system requires breaking down the knowledge “silos” that tend to form in most organizations because of division of labor and specialization. Indeed, as Dougherty (1992b) demonstrated in her study of new product development, successful firms are able to bring these different knowledge components together.

To establish the basis for such a holistic view, I first explore the relationships between the three knowledge components by examining two models of technological change. My conclusion is that these models need to be adapted for contemporary environments where change is continual. In contemporary environments there is a need to synchronize the creation and application of the three components of knowledge. I discuss how this can be accomplished in the concluding section.

**RELATIONSHIP AMONG KNOWLEDGE COMPONENTS**

Bohn (1994) provides one perspective on the relationship between know-how and know-why. He first identifies several stages of technological knowledge ranging from complete ignorance to complete understanding and suggests that these stages form a hierarchy. Know-how, on his ordinal scale, consists of an understanding of how production processes can be fine-tuned to reduce costs and change product characteristics. Such knowledge presupposes other knowledge in Bohn’s scheme. Specifically, it presupposes knowledge of measurements and of process control that, for expositional purposes, I have subsumed under the know-how construct.

It is possible to operate on the basis of know-how alone. For instance, our knowledge of how to bake a cake does not presuppose a knowledge of why the various ingredients interact to produce the specific type of cake. Such a situation is true of the manufacture of Steinway pianos or Stradivarius violins. Whereas the company has mastered the art of producing one-of-a-kind Steinways, they (or others) have not been able to find out why it is that their recipes each time result in the creation of excellent Steinways (Dunbar, Garud, & Kotha, 1996). Indeed, according to Henry Steinway, a lack of know-why is one reason that rivals have confronted difficulties in creating pianos comparable to Steinways. A lack of
knowledge of why something works can therefore form the basis for sustainable competitive advantage as causal ambiguity aids inimitability (Barney, 1991; Wernerfelt, 1984; Reed & DeFillipi, 1990).

Although such causal ambiguity may be the basis for the creation of sustainable competitive advantage (Reed & DeFillipi, 1990), an ignorance of why something works can pose a challenge for firms to the extent that customer needs are unpredictable and changing rapidly over time. To the extent that firms have to modify technologies to suit different customer needs, an appreciation of know-why also becomes important. Without an adequate appreciation of the underlying principles, changes in one element of the system may affect the performance of the entire system in a manner that is difficult to predict beforehand (Perrow, 1984). Know why is required to make informed improvements and changes.12

In Bohn’s exposition, know-how comes before know-why perhaps because it is possible to produce a technological system with know-how alone whereas the same statement cannot be said for know-why. Bohn suggests that know-why can be created from a know-how base through a learning process that involves tapping scientific models, running broad experiments across multiple variables to estimate models, and finding interactions among input variables. Such a process is well illustrated by Inland Steel’s efforts to introduce a computerized hot strip rolling mill (Gabarro & Lorsch, 1979; Dutton & Thomas, 1985). Summarizing these processes, Dutton and Thomas state that experience gained via learning-by-doing served to target R&D efforts toward technologically feasible alternatives.

Another set of relationships between these knowledge components is implicit in a widely embraced model of technological change commonly labeled as the two-stage, dominant design model (Utterback & Abernathy, 1975; Tushman & Anderson, 1986; Tushman & Rosenkopf, 1992). This model suggests that many technological systems evolve through an era of ferment followed by an era of incremental change. To this basic model I add a third stage: gestation.13

During the gestation period, advances in basic science and technology create the know-why base that is refined during the era of ferment. During the era of ferment firms experiment with different configurations of products before settling down to a set of product configurations that are most suitable for their customers. In other words, consistent with a thrust toward “exploration” (March, 1991), the focus during gestation and ferment is on the creation of know-why and know-what. During the era of incremental change, learning and knowledge associated with the “why” and “what” largely subsides subsequent to the emergence of a dominant standard. Vendors now focus their energies on the creation of the know-how required to mass produce standardized products and on “exploiting” the knowledge that they have generated during the era of ferment.14

Both models of technological change that I have discussed recognize the importance of all three knowledge components. The differences between the models lies in the lexical and temporal ordering of the creation and application of the various knowledge components. For instance, in the model proposed by Bohn the creation
and application of know-how comes before the creation and application of know-why, whereas in the dominant design model the creation and application of know-how comes after learning and accumulation of know-why and know-what have subsided.

I will not attempt to resolve these differences here. Instead, I will suggest an alternative model that I think is becoming important in contemporary environments characterized by differentiated and rapidly changing customer preferences. In these environments firms must continually update their knowledge of what their customers want. Firms must also possess the capability to synchronize the creation and deployment of appropriate know-how and know-why to be consistent with the continually changing know-what.

TECHNOLOGICAL AND ORGANIZATIONAL DESIGNS FOR LINKING KNOW-HOW -WHAT, AND -WHY

Historically, firms have been designed to generate these knowledge components primarily, though not exclusively, at different parts of an organization—know-how from those involved in the production process, know-why from researchers in R&D laboratories, and know-what from the interactions between sales personnel and a firm’s customers. In these traditional organizations the creation and application of know-why, know-how, and know-what occurs in stages as an idea progresses from R&D to manufacturing and then to sales, as in a relay team (Imai, Nonaka, & Takeuchi, 1985; Hayes, Wheelwright, & Clark, 1988).

In such organizations the asynchronous creation and deployment of knowledge components can render an asset into a trifile, or even a liability (Kreiner, 1996). First, these asynchronies can result in the magnification of errors as the relay race is run, thereby resulting in the consumption of scarce organizational resources (see also Fruin, 1996). Moreover, the differential rates at which knowledge at each of these stages may accumulate, decay, and transfer can result in competency traps (Levitt & March, 1988) and core rigidities (Leonard-Barton, 1992) as know-how and know-why become mismatched with what customers want.

To overcome this problem of asynchrony, Imai, Nonaka, and Takeuchi (1985) suggest “rugby” as a metaphor for the design of organizations. Such an organization will be designed to foster closer interactions between “thought worlds” (Dougherty, 1992a). Consistent with this metaphor, Eisenhardt and Tabrizi (1995) have found that the use of cross-functional teams can enhance the speed with which new products are introduced.

Complementing these insights are those offered by Kotla (1995) who has studied the National Bicycle Company (NBC) to describe how it is possible to link know-what and know-how. NBC has two factories: one that is dedicated to the traditional principles of mass production, and the other built around emerging principles of mass customization. The second factory offers customers different
bicycle configurations and identifies designs and sizes that are best suited to customer needs. Based on feedback that is received from this factory, the first factory dedicated to mass production is able to change its schedules to produce bicycles that are manufactured in mass but nevertheless are able to meet changing customer needs. The melding of know-what and know-how is facilitated by the rotation of personnel from the second to the first factory. Such a rotation is important to transfer tacit knowledge that is difficult to articulate and may not be transferable otherwise.

Both the rugby team metaphor and the National Bicycle Company case are illustrative of a larger phenomenon that is underway. Specifically, organizations are becoming flatter, developing closer links with suppliers and buyers, and establishing structures that facilitate knowledge-blending and knowledge-sharing (Hamel & Prahalad, 1994). This movement is bringing together different knowledge bases in a manner that allows for their co-mingling in a productive manner. These and other changes are occurring partly because of advances in information technologies that facilitate links between customers, manufactures, designers, and vendors (Huber, 1991). These changes are occurring also because of the need to coordinate different knowledge bases in a holistic manner (Garud, Jain, & Kumaraswamy, 1996).¹⁵

Indeed, a tighter coupling between know-how, know-what, and know-why can be created by the use of technologies such as computer-aided design (CAD), computer-aided manufacturing (CAM), and flexible manufacturing systems (FMS) (Adler, 1989). Underlying these production practices are a host of information technologies that allow for greater fluidity and rapidity of changes in the design and production of systems based on what customers may want, what is technologically feasible, and how easy it might be to manufacture the system (Best, 1990; Piore & Sable, 1984). These production technologies facilitate a shift in the locus of decision making about design, production, and use closer to the origins of relevant knowledge components. At the same time, these technologies allow for an integration of the different knowledge components in a meaningful and continual manner.

The advent of these information technologies allows for the encapsulation of activities with information, thereby making it possible to modularize knowledge systems (Langlois & Robertson, 1992; Orton & Weick, 1990).¹⁶ Modularity in design, production, and use requires a partitioning of technological knowledge into smaller manageable parts, each with its own know-how, know-why, and know-what (Piore & Sable, 1984). Partitioning makes it easier to synchronize changes in one knowledge component with changes in other components. Such a synchronization is accomplished by ensuring that each module, through its interactions with others proximate to it, creates a knowledge of what is important.¹⁷ Thus, the process of know-what generation is more proximate to each knowledge module, and involves continual interaction between modules.¹⁸ Moreover, modularity allows for the use and reuse of smaller units of the technological and organizational systems. As a result, modularization allows for rapid responses to a range of stimuli as relevant knowledge modules couple in various permutations.
Such a design is similar to the way our brain is designed (Garud & Kotha, 1994). Rather than being localized and sequentially activated (as in the relay team), knowledge modules in the brain are distributed and function in parallel. Each module is specialized and yet generalized. In coordination with others, modules are able to generate rapid responses to a range of stimuli. These stimuli are not from external sources alone. Knowledge modules also receive stimuli from others. Individually and collectively, these modules determine what needs a response. Very quickly, modules that are not relevant become silent even as the ones that are relevant become active.

We have written about systems that employ these design principles (Garud & Kumaraswamy, 1995). Specifically, we have written about firms using object oriented programming (OOP) to show how technological and organizational systems can be designed to operate in a modular fashion. OOP is a way of modularizing large software programs by packaging data and methods within objects. Unlike conventional "structured" programming in which data and operations are represented as separate entities, no such division exists with OOP. Instead, both are now "encapsulated" in units called objects that can exchange messages with other objects. The objects are then surrounded with an interface, creating a building block of information. These objects have "intelligence" in the sense that they know what their functions are, how these functions should be executed, and contain in them the algorithms that embody why they function the way they do.

The ability of these modules to be flexibly a part of a larger program is partly dependent on their functionality. It is also dependent on the way that each module interacts with others and the larger architectural environment that sets the overall rules of engagement. I will not go into these details in any great depth here except to point out that a modular view of organizations requires the formulation of meta routines of engagement and change. These meta routines, in turn, represent knowledge systems at a higher level of understanding.

DISCUSSION

Knowledge is an important facet of the emerging era of intellectual capitalism. Understanding how to create knowledge, maintain it, and put it to strategic use is an issue that concerns both practitioners and academicians. Such an endeavor requires that we make a distinction between different types of knowledge in order to understand their underlying properties, and hence manage them more effectively.

I have offered one such distinction in this paper. Specifically, I have made a distinction between the know-how, know-why, and know-what that constitute technological systems. I have suggested that these components accumulate through different learning processes, originate from different sources, and possess different properties with respect to their rates of acquisition, decay, and transfer.
As with any exploratory effort, my work raises as many questions as it attempts to address. Specifically, as I have suggested in this paper, it would be a fruitful exercise to revisit extant literature on knowledge armed with the distinction between know-how, know-why, and know-what proposed here. For illustrative purposes, consider the notion of absorptive capacity (Cohen & Levinthal, 1990). Absorptive capacity represents an ability to evaluate and utilize outside knowledge. Cohen and Levinthal suggest that such a capacity is largely a function of the level of prior related knowledge. Applying the distinction between know-how, know-why, and know-what, it would appear that absorptive capacity is knowledge-type specific. For instance, a knowledge of how to do something may create an absorptive capacity in know-how but may not lead to any absorptive capacity for know-why or know-what.

Indeed, the usefulness of adopting such a micro-analytic view is illustrated by Mansfield's (1988) work comparing the differences in emphasis placed on these knowledge components by firms in Japan and those in the United States. Mansfield found that Japanese firms are able to commercialize innovations based on external technologies much more rapidly and at lower cost as compared to their American counterparts. It appears from Mansfield's study that there are few significant differences in the resources allocated for applied research by firms in the two countries. However, there appear to be significant differences in the resources allocated for the generation and deployment of know-how and know-what by firms in the two countries. Thus, in this study, differences in absorptive capacity appears to be dependent on differences in the creation and deployment of know-how and know-what by firms in the two countries.

Mansfield's work underscores the usefulness of revisiting extant literature on knowledge to explore new insights that might emerge by making a distinction between know-how, know-why, and know-what. It is equally important for us to see how these knowledge components might be managed as a whole. Indeed, as Rosenbloom and Cusumano (1987, pp. 15-16) illustrate in their study of the VCR industry, firms that were able to harness all these knowledge components as an overall system were the ones that were successful in developing and commercializing the VCR. In their words:

Learning was the central task of pioneering in video technology. Each pioneer had to learn what functional performance consumers required as well as how to achieve it in design. What may have seemed to some in 1976 to be a dramatic and sudden innovation, was really the result of a series of steps. The successful designs thus emerged from an iterative process by which the pioneers came to understand not only the full range of capabilities inherent in the new technical synthesis, but also how to realize those capabilities in commercial-scale production and what value the market would place on them once achieved. Each successful organization learned these lessons largely by experience, that is, by offering products to users, studying their response, and trying again until they got it right—in effect, “learning by trying.”

This overall process represents what we have labeled as path creation (Garud & Rappa, 1994). Path creation involves the probing of various market segments with
different system configurations along with a willingness to change product configurations based on customer feedback (see also Brown, 1997). In the VCR case, path creation occurred over a fairly long period of time raising another aspect of knowledge management that I have alluded to. Specifically, if there is an asynchrony in the creation and deployment of the different knowledge components (as was evident in the VCR case), the notion of organizational memory becomes important (Walsh & Ungson, 1991). Organizational memory is a broad term that encompasses storage, retrieval, and re-application of knowledge components (see Walsh & Ungson, 1991; Garud & Nayyar, 1994).

Whereas the VCR technology developed over a relatively long period of time, firms are now operating in fields that are changing continually. Consequently, it is becoming all the more important to synchronize the creation and deployment of different knowledge components. I have offered some observations on how the creation and deployment of the knowledge components can be synchronized through the use of modularized designs that partition knowledge for easier use. In this context I also alluded to the use of technological practices such as CAD, CAM, and FMS to promote flexible integration of the three knowledge components. I have also alluded to some of the emerging organizational practices that are required to promote knowledge sharing in organizations. These are but some issues that require deeper inquiry.

CONCLUSION

I shared an early draft of this paper with my wife. Her initial retort was that I would have utilized my time better by fixing my son’s toy car that still has its wheel missing. However, my paper did serve a purpose; I think that we did come to some agreement about the nature of my engineering knowledge.

My complacency proved to be short-lived. Soon after the toy car incident, my wife’s PC refused to boot up. Turning to me for help, my wife asked whether I knew what had gone wrong. My diagnosis suggested that the auto-executable batch file on the hard disk had somehow lost the system command. Using a bootable system disk I proceeded to re-transfer the system command to the hard disk. Lo and behold, the computer booted up when it was turned on.

I was feeling quite pleased with myself until my wife asked me if I knew why the problem had arisen. She reasoned that this knowledge might help her avoid future disruptions. Sheepishly, I had to confess that I had no idea why her PC had malfunctioned. It seems that we engineers can never win!

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NOTES

1. For instance, knowledge of why something works at one level of generality represents knowledge of how it works at a deeper level of specificity. Consider Boyle’s law that specifies the relationship between pressure, volume, and temperature of any gaseous substance. As a science student in my high school days, this law helped me understand why the volume of a gaseous substance would decrease when its pressure was increased. However, I now realize that at a deeper level of specificity, Boyle’s law represents only a description of how gaseous substances behave to be explained by an understanding of the behavior of atomic particles. Given the hierarchical nature of knowledge, it is important to anchor the discussion at some level of analysis. I have anchored myself at the level of the technological system.

2. A distinction between these knowledge components can roughly be mapped onto distinctions that have been made by those in the cognitive science community on procedural, declarative, and episodic memory (cf. Tulving, 1985; Porac, Meindl, & Stubbart, 1996).

3. A knowledge of what customers want implies a knowledge of who these customers are. For simplicity I have subsumed knowledge of who under the knowledge of what in this paper.

4. Often, know-how transfer at the individual level is facilitated by an “apprenticeship” process; one that we call “learning-through-association” (Garud & Kumaraswamy, 1995b).

5. Such a process is currently unfolding in the multimedia field (see Garud, Kumaraswamy, & Prabhu, 1995).

6. In contrast, Walsh and Ungson (1991) suggest that individuals are ambivalent about understanding cause-and-effect relationships regarding decisions in organizational settings; consequently, Walsh and Ungson suggest that the “why” in any decision is likely to distort and decay quickly.

7. Barr, Stimpert, and Huff (1992) provide similar arguments for the persistence of mental models in organizational settings.

8. Such a coupling between customer preferences and firm capabilities have been explored using techniques such as “Quality Function Deployment” (Hauser & Clausing, 1988).

9. Although what a customer wants may change, relationships with the customer could be enduring. Indeed, the ease with which a firm can identify changes in what a customer may want can increase to the extent to which conduits of information flows have been established through an ongoing relationship.

10. A distinction between declarative and procedural learning may also be useful to understand differential rates of knowledge decay and transfer (Cohen, 1994). Whereas procedural learning builds knowledge of how to do something (know-how in this case), declarative learning builds knowledge of facts, events, or theories about the world (know-what and know-why). Cohen argues that procedural learning yields knowledge of lower verbal accessibility that decays much more slowly and is restricted in its range of transfer as compared to declarative learning. Employing this distinction, it would appear that know-how decays much more slowly and is restricted in its range of transfer as compared to know-what and know-why.

11. In the industrial sector Dutton and Thomas (1985) suggest that firms can operate on the basis of know-how alone in fields that do not require high scientific inputs for their development and operation. In such industrial fields changes in the underlying technology are guided via learning from production experience and/or learning from user experience in the case of product technology.
12. We asked Henry Steinway to reflect on his contributions to the company during his tenure as a CEO. One of his contributions, Mr. Steinway suggested, was to preserve the original design of Steinway pianos. Qualifying his comment Mr. Steinway added, “if it ain't broke, don't fix it.” He also added that the company had had to revert to its original design when changes that its designers made to the core design backfired (Dunbar, Garud, & Kotha, 1996).

13. This model of technological change incorporates two separate propositions about technology development. One of them is labeled technology push where advances in basic sciences and technology set the stage for the development of new products and processes. The second hypothesis is labeled as the demand pull, where market needs shape the rate and direction of technology development. As several authors point out, both forces are normally at work (Freeman, 1982; Mowery & Rosenberg, 1979).

14. March (1991) has written about the tension between exploration and exploitation that is implicit in this two-stage dominant design model. This tension has been documented by Dutton and Thomas (1985) in their study of United Diesel’s attempts to shift to standardized product designs and greater manufacturing efficiencies. Dutton and Thomas suggest that an increasing commitment to standardization may eventually imply reduced product innovation. In other words, a focus on the creation of know-how in manufacturing can reduce the focus on the creation of know-why in R&D (see also Utterback & Abernathy, 1975).

15. However, the extent to which such knowledge melding is possible is also dependent on the incentive and organizational structures that are put in place. Traditional structures (for instance those implicit in the SBU structures) create an incentive for knowledge hoarding as compared to knowledge sharing (Prahalad & Hamel, 1990; Garud & Kumaraswamy, 1995). Moreover, many incentive schemes that reward individuals rather than collectives spawn a culture where the melding of knowledge components becomes difficult. Elsewhere, we have offered some guidelines as to how organizational incentives can be shaped to encourage knowledge sharing (Garud & Kumaraswamy, 1995; Garud, Nayyar, & Shapira, 1997b).

16. Many have addressed the notion of decomposability (Simon, 1962; Garud & Kumaraswamy, 1993, 1995, 1996; Sanchez, 1995; Langlois & Robertson, 1992). Decomposing a systems into its parts entails knowledge of each component as well as knowledge of the ways in which the components of a technological system are integrated and linked together into a coherent whole (Henderson & Clark, 1990). Such architectural knowledge might imply an understanding of how a set of components are put together (the know-how), why the components interact with one another to provide the product functionality (the know-why), and the specific product configuration that customers might want (the know-what).

17. Modularity involves conformance to standardized “interface” specifications such that each part can be designed, produced, and bought independently of the other, they are still able to perform as a system when they are put together.

18. I thank Kusunoki San for suggesting that I articulate this point.

19. With respect to know-how, Japanese firms appear to spend much more of their resources for preproduction activities including preparation for manufacturing, and the design, construction, and acquisition of manufacturing facilities for the new product, as well as tooling and equipment. In contrast, firms in the United States appear to devote a much larger proportion of innovation cost to manufacturing startup than do Japanese firms. Manufacturing startup activities include the training of production workers, the “debugging” of the production facilities, and the resources expended to obtain an acceptable quality level. With respect to know-what, U.S. firms spend far greater resources than their Japanese counterparts on market startup activities that include marketing studies, advertising, and sales promotion before the sales of any appreciable amount of the new product (Mansfield, 1988).

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