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Energizing the Nexus of Corporate Knowledge: A Portal Toward the Virtual Organization

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Abstract

In the age of virtual organizations, managers and experts cease to be lone custodians of the corporate knowledge base. Knowledge must be shared across cultural and time-space boundaries to create strategic frontiers in global and virtual enterprises. However, we believe that organizations have barely scratched the surface of the "knowledge sharing game" played across virtual environments. In technology-based organizations, for example, technical knowledge must be meticulously captured and conveyed in a highly cognitive manner to have substantive benefits in raising the competence and productivity of globally-dispersed workers. In this light, we contend that richer forms of knowledge/media representations, such as virtual reality (VR) and 3D imagery, could be creatively utilized to enable improvements in knowledge management, especially within virtual workspace. We further argue that organizational learning evolves to a higher level only when knowledge management is radically improved and effectively exploits "organizational memory" with the aid of IT (Stein and Zwass 1995). This paper explores how a technology-based firm, APV Anhydro, has extracted technical knowledge from its experts and creatively presented such knowledge in rich media representations using VR/3D technologies. This enabled APV to share rich technical knowledge across its global marketing operations, and as a consequence, accelerated its organizational learning process.

1. INTRODUCTION

Emerging technologies have consistently been a focal point in organizational restructuring. Developments in IT are generally seen as a harbinger and powerful catalyst in the radical transformation of organizations (Davenport 1993; Hammer 1990). This transformation occasionally leads to the inception of the virtual organization (Davidow and Malone 1992; Lucas and Baroudi 1994). New technologies in the field of communication, networking, and multimedia have been the subject of several research projects within this context. Unfortunately, 3D technologies have eluded the same attention in IS research.

3D technologies (Yap 1998), such as virtual reality, 3D rendering, 3D animation, were once a technology cluster afforded only by elite institutions such as NASA and Boeing. This technology cluster gained popularity in the early 1990s with applications in cinematic special effects, computer games, and CAD-based design. The emergence of mass-based 3D applications was accelerated in the mid-1990s with the proliferation of cheap VR/3D software for home PCs. Due to their accessibility and affordability today, 3D technologies are within the reach of the architects, engineers, marketers, and those involved in visualization and presentation of complex products/artifacts.

Using the case study approach, this paper explores the innovative application of VR/3D as an IT enabler in the reengineering of a firm's global marketing process. Several in-depth interviews were conducted over a year using *key informants* (Yin 1991) and technology observations were done to ensure integrity of case data.

The research contribution is in furthering the discussion on the strategic importance of emerging technologies, especially when applied to (1) knowledge management and organizational learning objectives and (2) business process redesign in knowledge-based virtual organizations.

2. THEORETICAL FRAMEWORK

2.1 Knowledge Management

According to Zack (1998), experts have advised organizations that to remain competitive, they must effectively create, capture, locate, and share organizational knowledge and expertise, and have the ability to bring that knowledge to bear on problems and opportunities. The strategic value of organizational knowledge has been well discussed by Davenport, Jarvenpaa and Beers (1996), Nonaka (1994), and Winters (1987).

Due to the proliferation of knowledge-intensive products and the growing need for virtual teams/knowledge workers to access knowledge ubiquitously, knowledge requirements for business operations have become increasingly complex. Bohn (1994) and Robey, Rose and Boudreau (1997) consider *knowledge management* as highly crucial in managing information resources. While Nonaka (1994) and Romer (1995) stressed the need for explicating knowledge to improve its distribution/exchange within the organization, it is strategic to focus on *proprietary corporate knowledge*. Proprietary knowledge is intrinsic to the core competence/expertise of a firm and is often protected by patents, copyrights, and non-disclosure policies. This paper focuses on product knowledge, which is proprietary in nature.

The management of product knowledge is critical in technology-intensive firms as their competitive edge is to develop and market state-of-the-art products ahead of their competitors. In several cases, product knowledge is scattered across geographically-dispersed subsidiaries and needs to be integrated, structured, and linked. Zack contends that a main approach to knowledge management is to create an *integrative knowledge repository* as a common medium/reference for knowledge exchange and distribution across the organization. Zack also maintains that another broad approach to knowledge management is the use of *interactive applications* to improve the knowledge link between experts and learners. In this study, both approaches are descriptively illustrated.

2.2 Knowledge Representations and Organizational Learning

This paper adopts the definition by Robey, Rose and Boudreau of organizational learning: "An organizational process undertaken to acquire, access, and revise organizational memory, thereby providing direction to organizational action." This definition is indicative that the dynamics of *organizational memory* weigh heavily on the metabolism of organizational learning. Within organizations, knowledge repositories are seen as externalized structures of organizational memory. The effectiveness of these repositories depends on how it represents and organizes knowledge.

Current research literatures point to *knowledge representations*, in particular, and *knowledge management*, in general, as factors that can harness the strategic value of organizational memory. Ramesh (1997) and Robey, Rose and Boudreau contend that improvements in *knowledge representations* contribute to the evolution of organizational memory. In this connection, we see the potential knowledge-capturing capabilities of VR/3D technologies which allow the generation of richer forms of digital knowledge representations.

This study illustrates how a firm utilized IT to enrich knowledge representations, strengthen the nexus of corporate knowledge, and effectively convey complex technical knowledge throughout its global organization. With better knowledge representations and management, an organization develops a more conducive learning environment.

The authors believe that VR/3D imagery is a new revolutionary form of media and knowledge representation. This type of media has the capability to capture and externalize *mental models* (Senge 1990) once found only in the minds of engineers/architects.

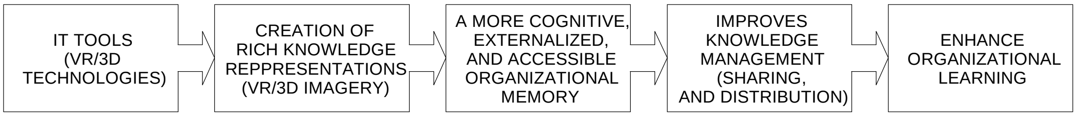


Figure 1. Contribution of VR/3D to Knowledge Management and Organizational Learning

When an engineer has a mental model of a product design concept, including its mechanistic processes and functions (i.e. a car engine, chemical factory), VR/3D representations enable the engineer to externalize the design concept and engineering knowledge of the product and visually demonstrate them to other members of the organization. It provides a vivid picturesque mind-sharing process of complex product knowledge with minimum equivocality. It addresses the issue posed by Nonaka: that knowledge is best exchanged, distributed, or combined among communities of practice by being made explicit. VR/3D imagery can richly explicate engineering/architectural knowledge needed in product design communication/collaboration and in the marketing presentation of complex product features and designs.

VR/3D knowledge representations have unique attributes that can enhance learning. The main attributes that VR/3D offer are (1) *it is a highly interactive visual media* and (2*) it is a media that provides an integrative and immersive perspective of concepts/models*. Interactivity here means that the user is able to get intelligent feedback from the knowledge representation. Senge (1990) discusses how reinforcing/balancing feedback loops enhance learning processes.[1] The concept of high-level interactivity is really analogous to a dynamic feedback loop that reinforces learning. The more responsive and interactive the knowledge representation is, the more it can guide users to correctly grasp the knowledge being conveyed. VR/3D objects can be given unique, real world characteristics such as movement, weight, gravity, and mass. A user can interact with VR/3D objects almost in the same way as with real objects. Media representations such as text, pictures, and video do not have this interactive attribute. In terms of providing an integrative perspective, Senge cites the tale of the three blind men where their limited perspectives prevent them from correctly describing an elephant. The lesson in this tale is that poorly represented or communicated knowledge breeds ignorance and is a stumbling block to learning. The integrative perspective that VR/3D media provides when representing product knowledge/concepts can remove this barrier. VR/3D allows a user to view a product concept from all perspectives in real-time real-space with a high degree of realism. VR/3D makes it possible for an engineer to fly-through and be immersed inside a computer-animated 3D automobile engine and see what is happening inside a running engine (like X-ray vision). This is information observed only in computer-simulation and not in real world environments. As such, VR/3D provides new ways of representing tacit knowledge needed in explaining complex products/artifacts.

2.3 Significance of Knowledge in Virtual Organizations

Davidow and Malone maintain that "the virtual corporation is a learning organization. At any given moment it is a collection of skills, talents, and experiences that reside in the minds of its managers and workers, and a body of information relating to its products, its internal structure, and its business relationships." In complement, Robey, Rose and Boudreau emphasize that "the advantage of information technology includes greater access to organizational memory especially from remote locations."

Broader knowledge access is a necessity for geographically-dispersed workers in virtual organizations since all members cannot be experts in a particular field of activity, task, or technology. While learning, remote workers need to be constantly supported by a rich integrative knowledge base and/or an efficient communication process in order to be effective in their jobs/tasks. For knowledge-dependent virtual organizations, a more externalized and accessible organizational memory is needed.

Experts who progressively document and contribute knowledge/know-how to the externalized organizational memory should encapsulate or have their knowledge encapsulated in representations that are easily understandable to other members of the

[1]Senge extensively discussed and illustrated why reinforcing and balancing feedback loops are the building blocks of *systems thinking.* He refers to systems thinking as the conceptual cornerstone that underlies all five learning principles discussed in his book.

virtual organization. In order to preserve knowledge in its richest form, it is critical that they utilize the most appropriate media/knowledge representations. VR/3D is a type of media that can perceptually simplify the presentation of complex product knowledge especially when conveyed across a global organization.

2.4 Technological Leveling

The concept of "technological leveling" (Lucas and Baroudi 1994*) is the strategy of substituting IT for layers of management and for a number of management tasks in virtual organizations*. Lucas and Baroudi stressed that this is used to exercise supervision on remote workers/groups. Technological leveling can be applied to knowledge management where knowledge resources can be effectively distributed to gear up remote workers for broader functional capabilities in virtual work environments.

In reengineering efforts leading to integration of different subsidiary organizations or business units, technological leveling is used to achieve synergy and a more effective management control within the integrated setting. In these situations, organizational memory and knowledge need to be coalesced at the earliest possible time to realize the full potential of the alliance. During this process, IT-enabled knowledge fusion and linkages can lead to significant improvements in organizational learning.

For firms metamorphosing toward the virtual organization (Bjørn-Andersen and Turner 1998; Lucas and Baroudi 1994), virtual components are created/utilized to substitute for physical components. IT provides the prerequisite for optimizing the utility function of virtual components. Since a substantial knowledge/know-how of experts can be captured and disseminated through digital storage, digital knowledge representations can act as a virtual substitute for the repetitive task of consulting with the organization's experts every time problems occurs. This curtails the need for experts to spend valuable time assisting knowledge workers.

3. THE APV ANHYDRO CASE

3.1 Background

The APV Anhydro Group is an international *engineering firm.* As a fast growing subsidiary of the transnational APV Group with turnover/sales of £772 million (US $1.158 billion) in 1996, APV Anhydro was reorganized to form a larger and more integrated organization. Three APV organizations, namely, *APV Drying and Evaporation*, *APV Pasilac AS Membrane Filtration*, and *APV Crepaco Separation Technologies, Inc*., were merged to form the new (1996-97) APV Anhydro Group.

The integrated APV Anhydro Group was responsible for designing and selling four *process technologies*, namely *drying, evaporation, membrane filtration*, and *distillation*. These *process technologies* are more accurately referred to as *separation technologies* as these technologies embody a range of technologies used in the technical process of separating liquids from solids and/or compound mixtures (Figure 2). These separation technologies are commonly applied in the dairy, food, beverage, pharmaceutical, and chemical industries. APV Anhydro has installed over 6,500 processing plants globally.

Marketing these technologies is an extremely delicate task. Mikkel Schnack, Group Marketing Manager, emphasized that *"selling separation technologies is not like selling coffee…due to the complexity of these technology-based products, it is a marketing process where one engineering expert is selling technology to another engineering expert."*

In response to the challenge of achieving synergy and integration in global marketing efforts, APV initiated an IT project, in late 1996, envisioned to enable radical improvements within its marketing process. The goal of this project was to create a tool anticipated to be an almost complete portable marketing knowledge-base. This tool was expected to address 90% of the global marketing presentation needs of APV Anhydro. In terms of hardware, the project took advantage of portable computers and digital storage (CD-ROM). For software, the project harnessed the power of VR, 3D rendering, and animation due to their capability to produce highly cognitive knowledge representations. This was in addition to a standard multimedia application that linked text, pictures, and videos using hypermedia principles. The result was a 700 megabytes interactive CD-ROM.

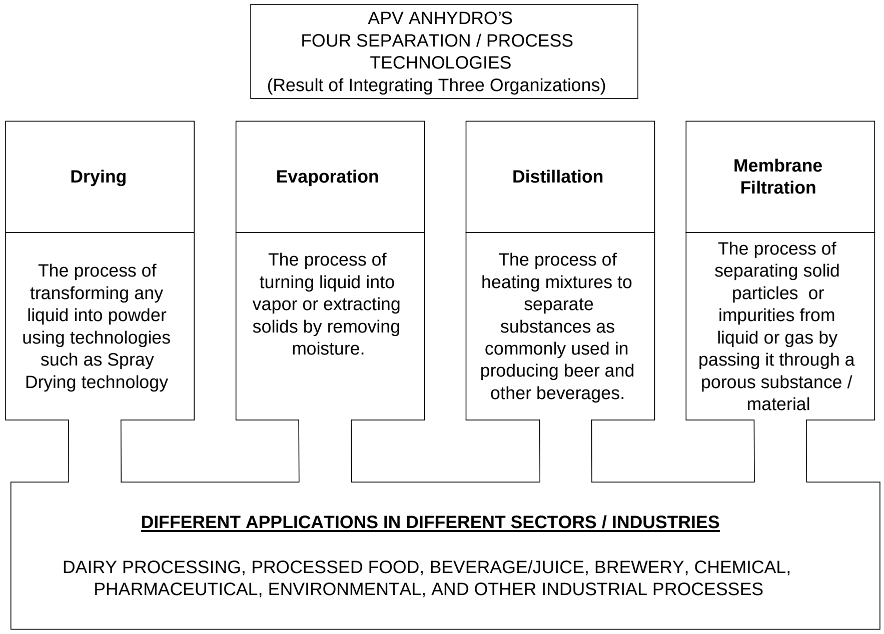
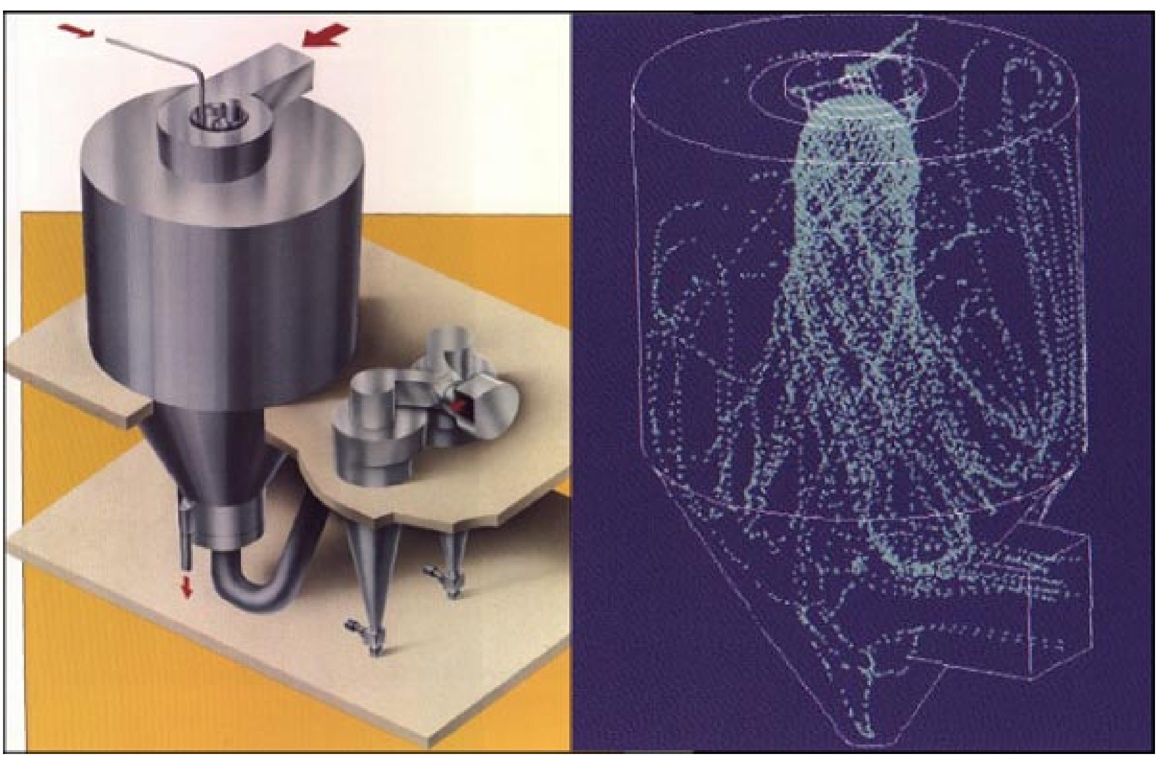


Figure 2. APV's Technology-Based Products

The combined text-picture media representations in the CD-ROM were intended to capture the information contents found in brochures and thus act as a *brochure substitute*. This *innovation* intended to save time in sifting through huge volumes of brochures/catalogues during marketing presentations. The newer forms of media—VR, 3D rendering, and animations—went beyond the function of substituting brochures. This media group represented another level of innovation. It manifests a distinct innovation characteristic in the area of visual media, because it shows how complex products function in real-time real-space via highly interactive and intelligently animated representations of its components and its internal processes (Figure 3).



Left: 3D rendered image of a piece of spray drying equipment. Right: the internal animated process of the spray drying equipment in the process of separating liquid and powder (a critical piece of information that cannot be instantiated by live video footage).

Figure 3. Images of Spray Drying Equipment

3.2 Organizational Challenges

The integration of three different organizations handling the four different technologies had been a major task for APV Anhydro. To capture synergy among three unique organizational structures located geographically apart, along with their corresponding marketing distribution channels world-wide, the global marketing process needed reengineering work. The former information system for global marketing could not respond to the new organizational challenge because it was a highly fragmented system. APV sales people did not have equal access to knowledge on all separation technologies and their diverse applications in different sectors.

The objectives of APV's organizational integration are summed up by the following: (1) improve capabilities and meet customer demands and services globally, (2) develop a more coherent business strategy in the global marketplace, (3) realize the potential synergy between four process technologies, and (4) move toward know-how and experience integration within the APV group and therefore offer better services to customers.

On the strategic level, there were two specific challenges that needed to be dealt with. The first was market expansion. Although the APV marketing organization served 42 countries in 1996, Schnack estimated that APV and its competitors have covered only 50% to 60% of the global market for separation technologies. The second challenge was the conspicuous lack of knowledge and ignorance within the sale force. Schnack described the knowledge deficiency problem:

> *We try to make sure that when sales people manage to get to the client's door, they appear professional and not wasting people's time. Hopefully, this gives us a better image. When an ignorant salesman talks, the reaction is "Go away, don't waste my time." As we sell knowledge, we suffer from ignorance.*

The key to resolving these challenges rested in two areas of slack:

1. *Selling Four Different Separation Technologies*. Before the merger, sales people in the three different APV organizations were traditionally trained to specialize in only one or two separation technologies. As such, they were not able to sell other technologies because they did not have the knowledge, training, and competence to present them intelligently and professionally to clients. This was seen by APV management as *a big opportunity loss* in marketing because there always existed the possibility that clients might actually need more than just one separation technology.

2. *Diverse Industrial/Sectoral Applications*. APV was also confronted by its sales people's lack of knowledge on the unique and complex applications of each of the four technologies in different sectors (such as dairy, food, beverage, pharmaceutical, and chemical industries). Sales people who were skilled in demonstrating the application of these technologies in the dairy sector normally did not have adequate knowledge to explain their alternative applications in the chemical or pharmaceutical sectors. Thus, a sales person who was effective in selling a particular technology in one sector was ineffective in selling exactly the same technology in another sectors due to non-exposure to its diverse/alternative applications.

3.3 The Role of IT

The IT project provided sales people with a highly educational presentation that augmented most of their knowledge-competence shortcomings, thus enabling them to impress even the more knowledgeable clients. The use of the CD-ROM minimized misinformation during marketing presentations because the knowledge it contained was gathered from the best minds within the organization.

The illustration in Figure 4 shows that before the IT project, a sales person's knowledge and marketing competence was limited to only one separation technology (i.e., drying technology) and one sectoral application of the technology (i.e. dairy processing sector). After the IT project, a sales person gained comprehensive knowledge on all four APV separation technologies and their diverse applications in various sectors. Schnack said:

> *If you are confident about dryer technology, you may not be confident about selling membrane technology, so you tend to avoid the subject. Now we have given them a marketing tool which enables them to be confident in what they are talking about.*

The new vision embodied in the IT project was to encourage sales people to be familiar with all four APV technologies and to present all of them even to clients who initially showed interest in only one technology. APV realized that these separation technologies could actually be marketed in a more integrated fashion and diversified range of markets. The IT tool could help

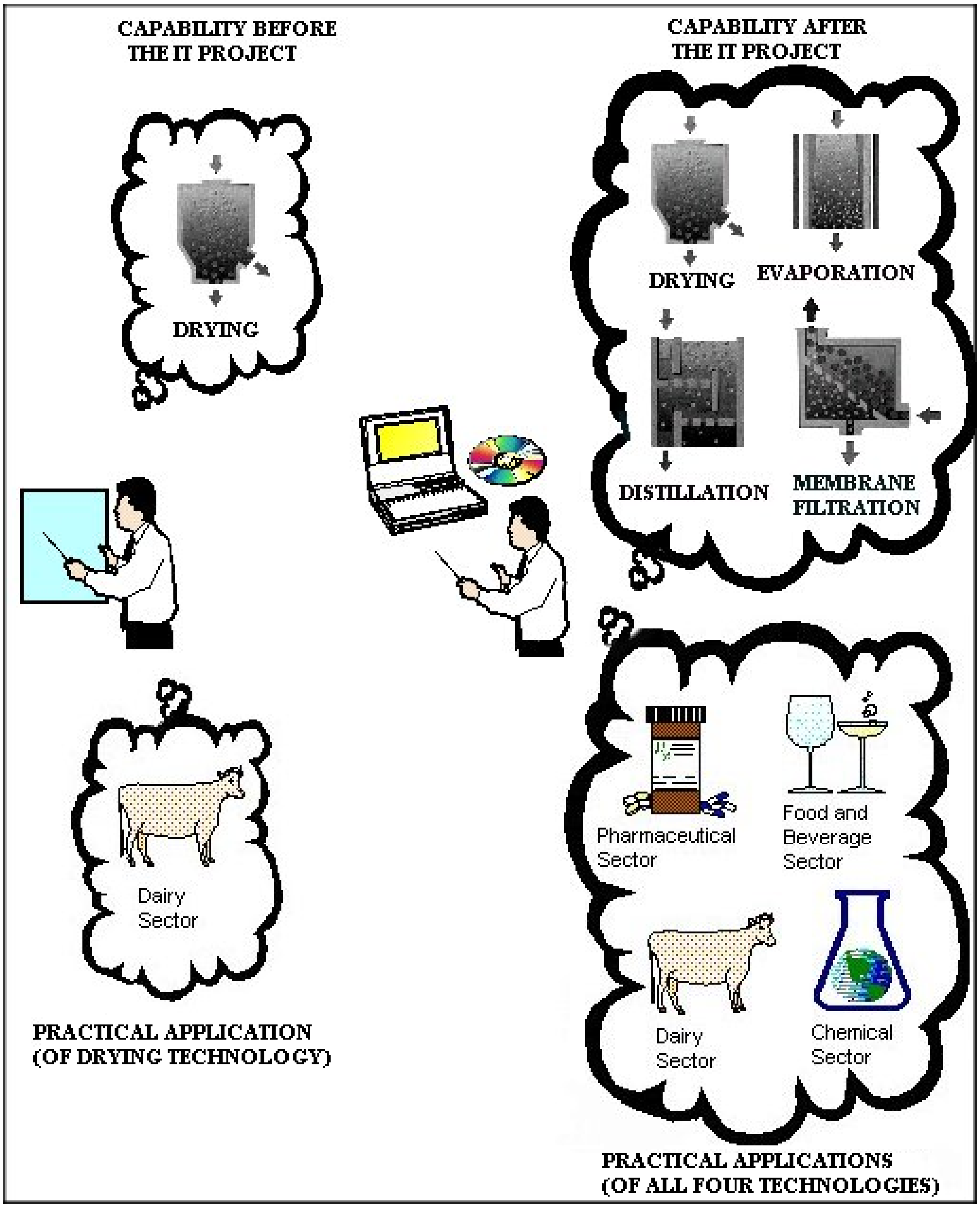


Figure 4. Knowledge and Competence of Sales People to Market APV Technologies and Their Practical Applications in Different Industries

a sales person gain insight, knowledge, and confidence to introduce these products even in markets they had not penetrated. Without IT, it was nearly impossible for a sales person to have in-depth knowledge and expertise in all four process technologies at the same time, let alone each of their diverse industrial applications. With the aid of rich 3D representations backed by a multimedia knowledge base, even neophyte sales people could do a good presentation on all technologies.

APV decided to use VR/3D imagery in presenting its products because rich and dynamic visual information is easier to communicate. Picturesque non-language-based media represents knowledge on a more universal ground as it is not prone to semantic misinterpretation. Moreover, products that are still in the conceptual stage, and therefore *physically non-existent*, cannot take advantage of photographs or videos which require the presence of physical artifacts. Lean media was not rich enough to convey the complexity of APV's technology-based products. This was why APV decided to portray a non-existing plant as a virtual plant to show clients how it will realistically look from the inside out when it is physically constructed in the future.

The VR walk-through and 3D representations focused on critical parts of plant concepts, which were essential selling points for clients. It also strengthened client involvement in the design process. As Schnack described,

> *if we can show the customers the plant and walk around the plant with the customer, we can build confidence with the customer…that we know what we are doing. He can see that the piping is laid decently and not made in a stupid way. He can also see that we have thought about the lay out carefully. He can then say, "I would like this changed"…and as soon as he starts doing that, we have sold the product to him, because he is now involved in the design conceptualization.*

Schnack added that

> *3D animations are a difficult part of this [media] technology, but it helps a lot in understanding what we talk about. Our people are more proficient…they are more confident in what they are presenting. And you actually make sure that they talk about it, because we cover four different complex technologies.*

The confidence in sales people was based on the media's ability to augment their knowledge shortcomings. The richness of VR/3D representations minimized their need to explain extensively.

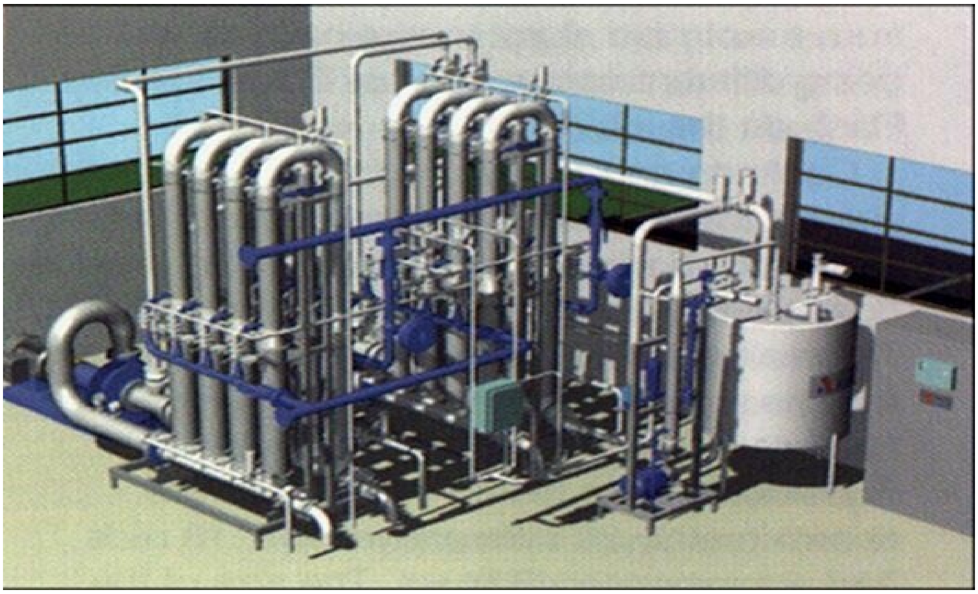


Figure 5. APV's Vegetable Juice Processor in a 3D Rendered Representation

3.4 Implementation Phase

Birgit Nielsen, deputy marketing manager of APV Anhydro, described the process.

> *We started making layout sheets with groups of slides and information we wanted to explain…not the text… but the content of the slide. So we had a layout manual. We continuously tried to identify the information content we thought was needed for the whole presentation. We discussed the information content with about 50 people. We are three companies and we discussed with individuals in different parts of our company to make sure that we covered what we wanted to do. It took us a month to conduct these consultations. Later on, we have been running back and forth and checking whether it was still valid or whether it should be formulated in another way. One thing is to finalize the content and the other is to finalize the presentation. When we hired 3D experts to create 3D animations, it was not just something that was moving. It was an animation that explained a process. It's an interactive animation. We also had to make a flowchart map of the individual slides where we could jump from one slide to another during the multimedia presentation…to show where the information links are. Then we produced the slides on paper and gave it back to the people we consulted so they could check the technical content and the flow of thought…whether it was correct to go from slide 1 to slide 2 or 3.*

The next phase, in April 1997, was to distribute a sample of 10 CD-ROM to be used in pilot sites. Nielsen said that

> *ten people were forced to source specific jobs from the CD-ROM. I made some "jobs" and said "please try to see how you would make a marketing presentation covering this job." So they gave a lot of feedback.*

The feedback was on how this tool fared as a presentation aid. Schnack said, "*Before we changed the CD-ROM, we asked them what is good and bad…what is your recommendation?"* This was where sales people contributed most to the design of the knowledge-base system.

When asked what information was needed to enhance the quality of the CD-ROM presentation, Schnack said that

> *it was information on the same product, but we wanted it to be market specific. So if we go to a specific sector or market, then we have a presentation regarding a sector's application of the technology. For each technology, we have a detailed description for each sector.*

These changes caused a four month delay in the project. Schnack believed that the delay was worth it because clients diversifying their businesses (i.e., from dairy products to food processing) could learn how these technologies were applied in other sectors/areas.

By October 1997, 50 CD-ROMs and laptops had been distributed in different parts of the world. In essence, almost all marketing channels received one copy each. Schnack estimated that the marketing offices requested an additional 200 CD-ROMs.

3.5 Initial Feedback on Technology Usage

Nielsen related how a salesman improved sales with the CD-ROM,

> *One salesman had to present spray drying technology to the customer, and in between, the things that we expected to happen happened. They said, "Oh, so you do membrane filtration as well? We would like to recover our cleaning and waste water." And the salesman said, "We can cover that problem by membrane filtration." The salesman was able to show APV's membrane filtration technology. He could never have done that before, because he would not have prepared any material to show membrane filtration as the presentation was only for spray drying technology. With the CD-ROM, the marketing materials for membrane*

> *filtration were complete. So the customer realized that we had a broader scope of products than they initially thought we had.*

The CD-ROM has a unique presentation of the membrane filtration process. Nielsen commented,

> *You cannot make a video showing how molecules are going through a membrane…that's not possible. We have a membrane filtration animation and an interactive take where we show different possibilities of the particles going through the membrane.*

The CD-ROM was also aimed at projecting the image of APV as a highly capable technology firm. According to Nielsen, the CD-ROM achieved this as well. A salesman commented that clients were more interested in the visual effects of the CD-ROM than in what he was presenting, but he got the orders in the end. Schnack said,

> *It is a gimmick to some extent. But bear in mind that it is an educational tool for customers who do not know the technology and for the sales people. For that, the power of 3D animation is a clear shot.*

Snack and Nielsen said that it was common for customers to ask for copies of the CD-ROM. However, the CD-ROM could not be distributed publicly as it contained proprietary corporate knowledge.

4. DISCUSSION

4.1 Organizational Virtuality Through Ubiquitous Knowledge and Remote Learning

To create a competitive marketing organization, APV had to move toward a more virtualized knowledge-based organization. Essential product and marketing knowledge were properly captured, linked, and stored as one multi-purpose knowledge-base, and then made *equally accessible* to all sales channels worldwide. APV achieved its goal of providing an *omnipresent* body of technical knowledge that fully supported its global marketing efforts.

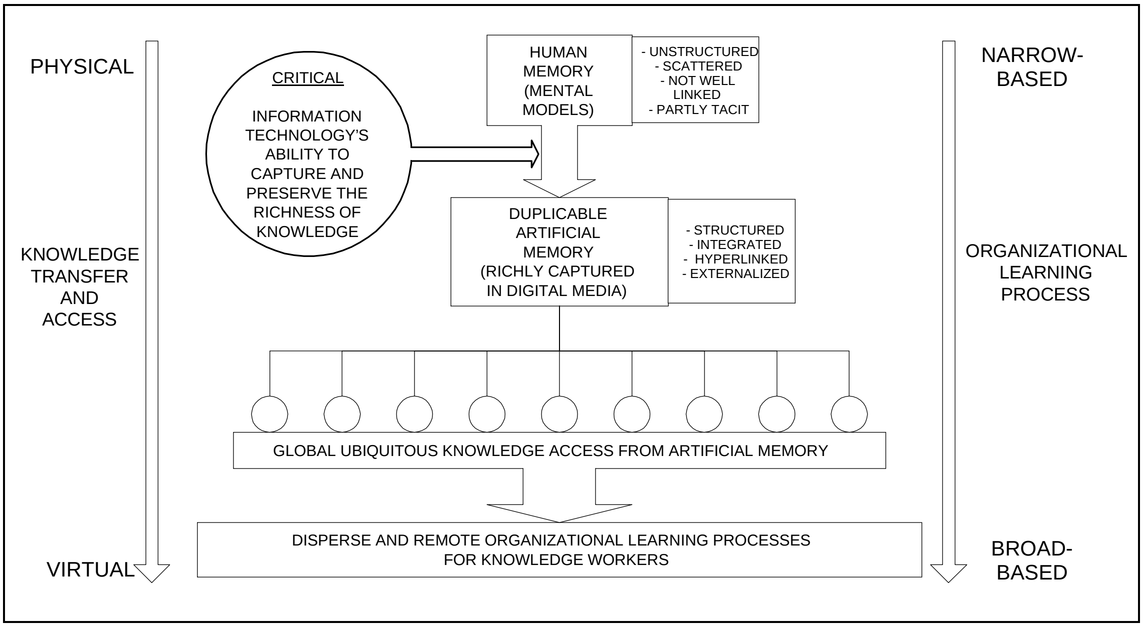


Figure 6. Virtuality and Broad-Based Learning as a Result of Memory Alteration

APV virtualized the nexus of corporate knowledge when it systematically gathered, captured, richly represented, and transferred a crucial chunk of organizational memory from "human" to "artificial" and distributed it for ubiquitous access (Figure 6). Walsh and Ungson (1991) view organizational memory as knowledge being stored in both human and artificial repositories.

APV's initiative supported Robey, Rose and Boudreau's claim that alterations in organizational memory lead to changes in organizational learning. The shift from human to artificial memory transformed the organizational learning process from narrow to broad-based learning since artificial "digitally-stored" memory has the flexibility of being duplicated and distributed across the global organization. Even in the absence of APV experts in remote operations, learning can still take place due to the interactive and portable knowledge base. In this manner, knowledge transfer/access within APV attained a certain level of virtuality, thereby enabling a more global and broad-based learning process.

The transformation from human to artificial memory entails a process that intuitively links, structures, and integrates knowledge, and this is a difficult task. This is actually an information filtering process, which involves thorough planning, creativity, several discourses, and organizational interaction as described section 3.4. This filtering process is needed to explicate knowledge. For this process to have an impact on the metabolism of organizational learning, the *critical element* is in how knowledge is richly/wholly captured and preserved when encapsulated in artificial digital media. Cognitive media representations such as VR/3D need to be used when sharing and digesting knowledge in virtual workspace so that any possible misconception of the knowledge being conveyed will be minimized.

Organizational virtuality is also said to be achieved through the *global uniformity or sameness* of knowledge and competence (Figure 7), a characteristic that suggests that the organization has transcended or crossed-over the limits of *mind-sharing boundaries* caused by geographic, cultural, institutional, mind-set, and cognitive limitations.

With IT, all technical product knowledge accessible to APV sales people in Europe was the same in terms of *information content* and *media representation* as those accessed by APV sales people in the remotest regions of Asia. Location and time made no difference in accessing and learning from the same body of technical knowledge. This provided sales people with a more *equalized level of competence* to carry out their tasks/functions.

The achievement of what Lucas and Baroudi coined as *technological leveling* is clearly seen in the multiplication of knowledge with digital media technology *standing in* as an effective *functional substitute* for experts (the knowledge source). This drastically lessens, if not eliminate, the function of experts in assisting remote workers with their knowledge deficiencies when fulfilling client information requirements. In effect, the organization is flattened by technology as a hierarchical layer is removed in the process of retrieving and disseminating knowledge (Figure 8), thereby altering the hierarchical structure within the organization. Again, this scenario only holds when knowledge is *richly* captured in "interactive" digital media.

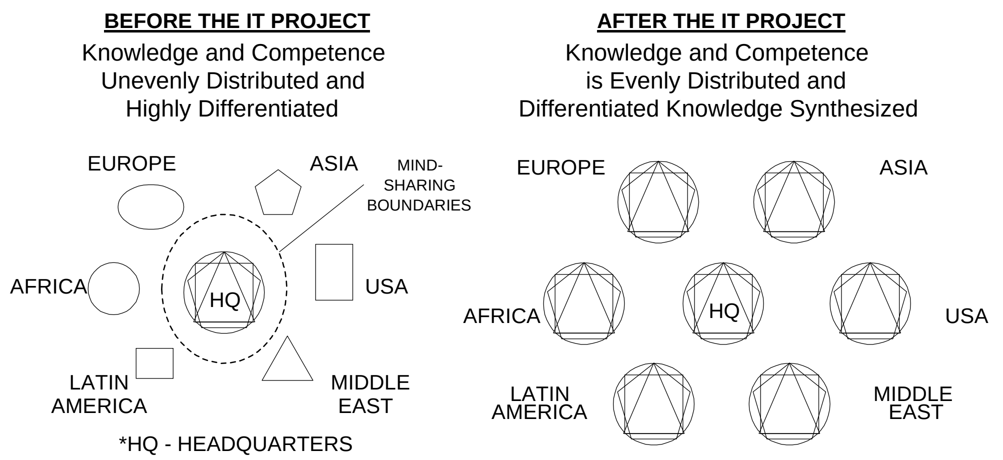


Figure 7. Distribution and Differentiation of Knowledge and Competence in APV

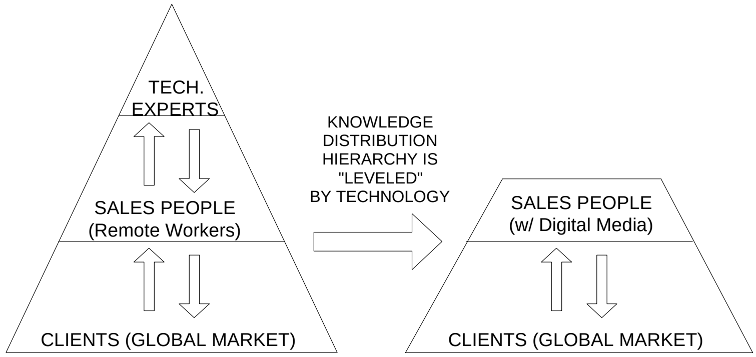


Figure 8. Client Requirements for Technical Knowledge are Served Faster as a Result of a Flatter Hierarchy in Knowledge Distribution

Schnack described how expert knowledge had been captured by technology after long group discussions and consensual decisions on what *expert knowledge content* should be.

> *We tried to pin down our very best engineers [experts] and ask them, "How do you explain our product's features, functions, and applications?" Discuss that in a larger forum and say, "Can we all agree that this is the explanation we would like to convey?" If yes, we put them into digital media.*

Organizational learning in this case supports the view proposed by Argyris and Schön (1978) and Fiol and Lyles (1985) that the contribution of learning is in enhancing organizational effectiveness. When APV pursued this reengineering effort, an expanded learning process was anticipated to improve global sales/marketing competence and, in turn, boost the sales and profits of the organization. New technical product knowledge and marketing competence enabled the global sales force to penetrate a broader range of markets and sectors.

4.2 Strategic Fit between IT and Organizational Knowledge Requirements

When APV initiated this project, it seriously considered the *strategic fit* between its learning objectives and its chosen IT solution. Robey, Rose and Boudreau postulate that "before an organization can leverage IT to enable organizational learning, the appropriate technologies must be implemented and used." APV had to ascertain the appropriateness of the media technology used for representing knowledge extracted from its experts. It needed to match the complexity of its product information with the richness of media representation to effectively preserve the integral essence of the knowledge being conveyed (Figure 9).

Visual media is highly important when presenting product concepts/knowledge. Simple products like furniture, can be easily depicted by pictures/videos. However, when presenting complex machinery or processes, pictures and videos are inadequate. Figure 9 illustrates the unique advantage of using 3D and VR over other visual media in conveying technically-complex product design information. Pictures are non-interactive media and APV found it difficult to explain how processing plants work by presenting pictures of it. Video footage, although three-dimensional in presentation, is likewise limited because it could not capture mental models of engineering design concepts. Video footage is also a non-interactive media and therefore limited in articulating tacit information. Lastly, video footage could not capture perspectives that are inside enclosed objects or machinery. On the other hand, interactive VR/3D perspectives can give clients a tour inside enclosed or even sub-atomic objects and let them see/experience what is happening inside internal/microcosmic processes. These perspectives are needed to articulate technical product features (as depicted in Figure 3) and only VR/3D media has a capability to provide these perspectives.

VR/3D representations also allow a *higher level of interactivity* and *richer integrative perspective* when communicating product knowledge. As postulated in section 2.2, these two attributes are key to addressing the learning process because they provide a better feedback loop for the user. The more the audience can interact *(level of interactivity)* with the visual representation of the product, the more the audience can internalize and learn the product's features and process mechanisms. The ability to view the visual representation in several perspectives *(richness of perspective)* also gives the audience a more holistic perspective of the product concept. Highly navigable and interactive VR/3D perspectives considerably enhance the *level of cognition* as they create an immersive sense of virtual space.

The technique of immersion involves the user with the knowledge representation to a greater extent. VR/3D gives the illusion of real space and intelligent interaction with virtual objects. When knowledge is encapsulated in a more cognitive/understandable form, it has less chances of being misinterpreted/ambiguous *(level of equivocality)*. For this reason, VR/3D is more appropriate for encapsulating complex technical knowledge as this type of knowledge is more prone to equivocality.

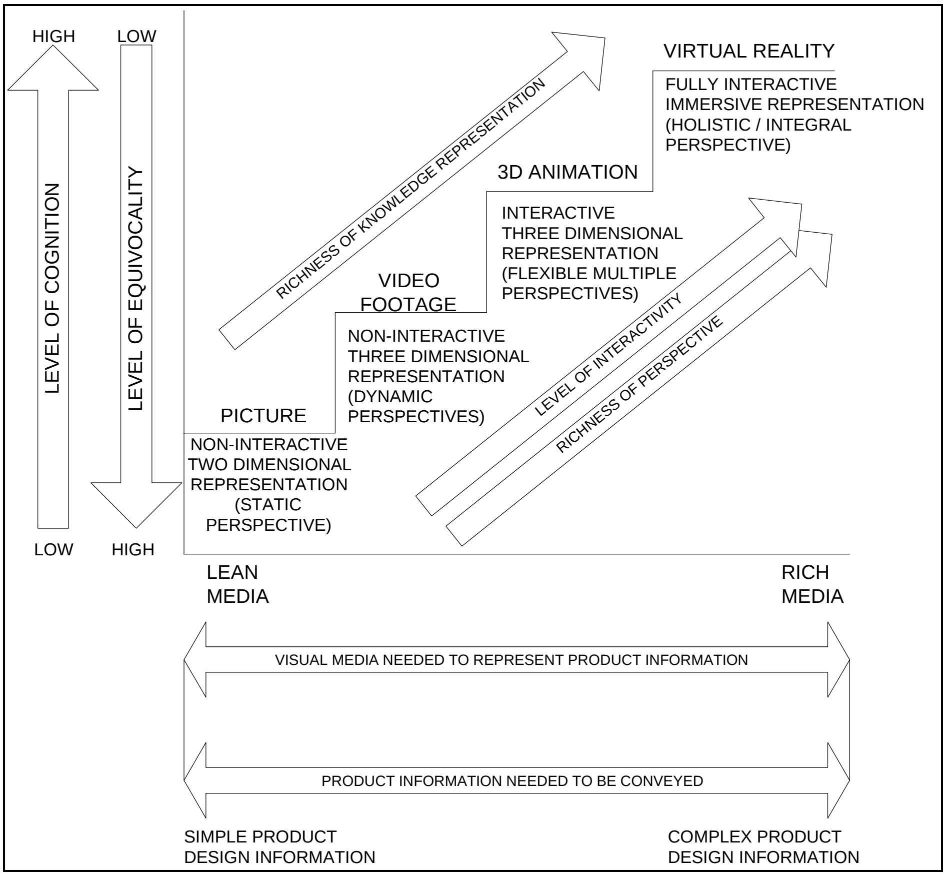


Figure 9. Media Needed to Represent and Communicate Technical Product Knowledge

The assertion of Robey, Rose and Boudreau that knowledge representation improves organizational memory and eventually leads to developments in organizational learning is the focus of this discussion. Knowledge representations do alter the cognitive maps, the mental models (Senge 1990), and can strengthen the nexus of knowledge in virtual workspace. In this case, VR/3D allowed engineers/sales people to have lucid *shared mental models* of the technologies they were marketing globally. Therefore, the case supports the theoretical assertions in this paper that knowledge representation is an important contributing factor to the effective management of knowledge and that it also helps bring forth a more virtualized knowledge-based organization.

4.3 Critical Success Factors

The basic strength of this IT project is grounded on two factors. The first is attributed to how carefully *information content* had been chosen, planned, and prepared over several months with the help of several technology experts. The second strength is due to the considerable attention paid to *how information was linked, structured, packaged, and presented*. The project proponents made sure that appropriate media were used to represent knowledge distributed across a globally-dispersed organization and a culturally-diverse market environment. Therefore, aside from technology, a critical success factor was the creativity, involvement, and effort of the people behind the project.

The study by Robey (1995) regarding *contradictory organizational consequences of IT* argues that it is not just advances in IT but other factors like *organizational culture, value of information, institutional values, and learning* that determine the success/failure of IT. In this case, the group handling the IT project reflected a strongly progressive management culture. Correspondingly, the sales people highly valued the information made available to them. The project also flourished in an institutional environment that had the full support of managers and experts. Moreover, sales people were not forced to use the technology. Instead, they were persuaded to examine the technology's advantages and how it could ease their jobs. This made technology adoption smoother.

5. CONCLUSION

This study illustrates that VR/3D technologies, through their ability to generate rich knowledge representations, are a vital innovation in capturing the complex essence of expert knowledge. In this connection, two significant changes are bound to occur when an organization is able to effectively preserve the richness of expert knowledge in artificial memory. First, the organizational structure can easily shift from physical to virtual. Second, organizational learning is expanded from a narrow to a broad-based process. These changes take effect because, through the combined force of *rich knowledge representations* and *ubiquitous artificial memory*, expert knowledge/know-how can be effectively shared in virtual work environments. And thus, mind-sharing boundaries in knowledge-dependent organizations disintegrate and finally enable a more virtualized organization. In this light, we see VR/3D-based knowledge representations marking a new era for technology-based organizations in their quest for effective sharing of technical product knowledge and know-how across virtual environments.

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