4

The knowledge base for product development

The ability of a company to build a knowledge core and continuously create new knowledge is critical to the success of product development. There are four areas where knowledge is needed for product development:

- the different cultures of the world, their needs, wants and attitudes, and how they can assimilate and absorb new products;
- basic knowledge and skills of present raw material production and food processing;
- high technological knowledge and problem-solving skills to develop new technologies;
- product development systems and organisation.

Basically this is applying the total technology concept to food product development – society, company environment, company resources, knowledge, organisation, techniques and the practice of product development. Management selects and integrates the knowledge in the company, and provides the conditions for knowledge to be created. There has to be a communications system in the company so that knowledge spreads and grows throughout the company. Knowledge is dynamic, causing change. It is important to recognise that knowledge is not just information and databases, but it is part of the active development in the company in organising the present system and activities, and also in developing new systems and activities. Information can be the basis for revealing and creating knowledge, but knowledge is in people – in their heads, in their problem-solving skills. It is in their understanding of the interaction between technology and society and also of the specific interactions of the consumer and the product, the worker and the processing plant, the salesperson and the retail outlet, the cook and the kitchen, and so on.

Knowledge causes change; information is the basis of change. Today, there is increasing emphasis of this being a 'knowledge society', as if knowledge is something new. Knowledge has been around for a long time; there are periods when it increases and sometimes, as in the Dark Ages, when it seemed to lose ground. What is different at the beginning of the new millennium is that communication between people has been made much easier; and communication does increase knowledge if the information is absorbed and used in the minds of people. But what does this increasing interchange mean to the food industry?

4.1 Technology, knowledge and the food system

Technology takes knowledge and creates products, processes and services for the use of people. At the heart of technology lies the ability to recognise a human need or desire (actual or potential) and then to devise a means – an invention or a new design – to satisfy it economically. Having done so, the model or prototype has to be scaled up and adapted to become a marketable item. The process of turning the full-scale product into something that satisfies market requirements of safety, cost/profit effectiveness and customer acceptance is a difficult one (Cardwell, 1994). A company not only has to have a store of knowledge but it has to create knowledge during the development of the product, process and service. It also has to connect different types of knowledge during the development – technological, commercial and organisational. After the development, it has not only transformed the knowledge into practical applications but it has increased its own store of knowledge by the knowledge it has created.

Two types of knowledge are recognised – disembodied (before and during development) and embodied (after development). The disembodied knowledge goes eventually to the embodied product in product development:

Disembodied knowledge --- *Disembodied innovative activities* --- *Embodied product*

That is:

Tacit knowledge in people's heads + Explicit (codified) knowledge in records --- Knowledge creation in PD Process --- New product

There are four important areas of disembodied and embodied knowledge: technology, technological change, innovative activities and technological indicators that are important for product development (Evangelista, 1999), as shown in Table 4.1. A company has a stock of technological knowledge, and then generates more knowledge during its innovative activities to produce productive assets, including products, plants and marketing systems.

In product development, as in all engineering and design, there is a major use of the knowledge that is in people's heads from their education and more importantly from their experience – called either tacit (as used in this book) or embedded knowledge. There is also use of recorded knowledge in reports,

Table 4.1 Concepts of technology

Disembodied
Disembodied technology: stock of technological knowledge both embodied in people and expressed in a codified form.
Disembodied technological change: process of advancing technological knowledge.
Disembodied innovative activities: activities carried out at the firm level to generate or develop new technological knowledge.
Disembodied technological indicators: R&D expenditures and personnel, design and engineering activities, patent and licence counts, technology flows measured by the technological balance of payments and bibliometric data.
Embodied
Embodied technology: stock of technological productive assets consisting of machinery, equipment, plant and operating systems (both tangible and intangible).
Embodied technological change: accumulation of new technical assets (machinery, equipment, plant and operating systems).
Embodied innovative activities: innovative activities consisting of the use or adoption of new productive assets with enhanced technical and technological performances compared with those used before.
Embodied technological and innovative indicators: investment in new machinery, equipment and plant incorporating new (or not yet used) technologies; indicators measuring the adoption and diffusion of embodied technologies.

Source: From Evangelista, 1999, by permission of Rinaldo Evangelista and Edward Elgar Publishing Ltd.

textbooks and journals, called either explicit (as used in this book) or codified knowledge.

4.1.1 Knowledge in the food system

In a study of the Italian industry, Evangelista (1999) placed the food and drink industries in the investment intensive sector. The other sectors were:

- R&D/investment intensive;
- R&D (research and development) and D&E (design and engineering) innovators;
- technology users.

In his investment intensive sector, investment activities play an important role, while research, development, design and engineering play marginal roles. Process innovations are very common and innovation performance is linked to investment in technologically new machinery and equipment. Other processing industries, chemicals and sugar in the investment intensive sector and pharmaceuticals in the R&D/investment intensive sector had higher research, development, design and engineering activities. Pharmaceuticals had high R&D and D&E expenditures accompanied by medium or high levels of investment in machinery, innovation being clearly oriented towards the introduction of product innovations. Comparing companies in Europe in Table 4.2, this greater emphasis

Table 4.2 Product and process innovations in European companies

	Percentage of firms introducing		
	Product innovation	Process innovation	Product and process innovation
Mechanical machinery	92.8	69.8	62.6
Chemicals	91.6	75.5	67.1
Food, drink & tobacco	70.3	93.6	63.9

Source: From Evangelista, 1999, by permission of Rinaldo Evangelista and Edward Elgar Publishing Ltd.

on process innovation in the food industry was clearly shown (Evangelista, 1999).

One recognises that food manufacturing is essentially a supplier-dominated industry with ingredients from the chemical industry and large food ingredients processors and equipment from mechanical/electrical manufacturers. Knowledge is bought in by food manufacturers from the suppliers, there is often less creation of knowledge than in the supplier industries (Hood *et al*., 1995). This knowledge generation and transfer is emphasised at the food congresses where a large number of suppliers not only exhibit their products and equipment but also give or sponsor many of the papers at the meeting. An interesting recent example demonstrating the limitations of product development when relying heavily on outside sources of technology was shown by Martinez and Burns (1999) when studying the Spanish food and drink industry. They found product technology was predominantly in-house generated, process technology combined internal development with external acquisition mainly from equipment suppliers. Purchase of equipment emerged as the main source of external technology acquisition as opposed to information gathering procedures. This reliance on externally generated technological developments had brought about low levels of technological independence in general and process technology in particular. The importance of in-house technological capabilities in product and process innovation, indicates the problems in product development a company and indeed an industry faces if it relies largely on external sources as opposed to internal developments. Is it time for food manufacturing to include more R&D and D&E in product development so as to produce a more sophisticated technological content in consumer food products? The food manufacturing industry is probably never going to be a high technological industry but there is a need for a different balance between R&D, D&E and capital investment in plant as these are joint determinants of the performance of companies. Wallace and Schroder (1997) made the following statement which the management of food industry development might ponder:

> Research and development in the food industry is a well-recognised case of market failure with its private costs and benefits differing from its social ones. The end result is an under-investment in R&D by private firms and attempts to justify government supporting it. The question is how to solve this dilemma. In the meantime, increasing masses of scientific and technical information and analysis are being super-imposed on a world wide background of rapid legal, political and social change.

Organisations can be grouped as functional, processed-based and societal knowledge-based. This means that a company can be based on functional departments such as marketing, production; or it can be an integrated technological entity; or lastly it can be a technological entity integrated into society. Is the food industry, which has been mainly functional, moving towards an integrated technological organisation with management based on societal knowledge? If so, the knowledge needed in the industry will have to increase exponentially.

4.1.2 Creation and movement of knowledge in the food system

The passing of knowledge between suppliers and food manufacturers emphasises that one cannot think of a part of the food industry by itself. In knowledge creation, each part of the food system is affecting knowledge in another part. In primary production, knowledge creation has been very much government-financed and often government-led. In early years, farming and fishing were essential for the production of food for the population, and were often the occupations of many individuals and families. Governments therefore felt that R&D in food production was their social responsibility. Today scientists in private and publicly managed agencies do significant basic and applied research. Governments are still funding agricultural research from government revenues and often organise agricultural research. For example in the United States, the US Department of Agriculture is still a major player in agricultural research and State governments are also involved. Internationally, there are also United Nations organisations and other world governmental agencies funding and organising agricultural research. The roles of the different public agencies and private firms are intertwined in complex ways (Alston *et al*., 1997). Surprisingly, research for the fishing industry has never been so extensively government funded, and one might think that the over-fishing and lowering of fish stocks has been due to lack of knowledge as much as human greed.

Distribution research has also been an area of government research for many years because of the need to store and transport food to urban areas, and internationally. So knowledge increase in the food system is still dependent on governmental funding and support, except for the food ingredient processing and consumer product manufacturing which have been among the low spenders on R&D related to sales among the industries based on process engineering. This may be due to its only recent emergence as a science-based industry, the

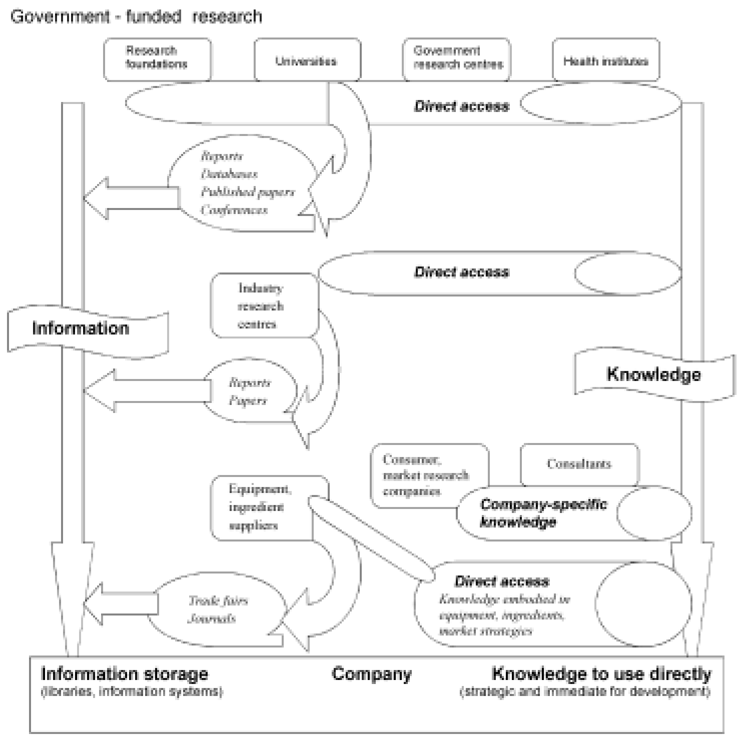


Fig. 4.1 Information and knowledge in the food company from outside R&D.

marketing domination in many food companies, the difficulty of controlling intellectual property in the food industry, and the small margins on which the food industry works (Earle and Earle, 1997). Much of the knowledge in the food manufacturing company has been created in incremental product development, which unfortunately has often not been recorded so it is not an explicit knowledge base for future product development. Much of the private knowledge in the food industry is in the large multinational companies, and tends not to go into the public arena even for the teaching of students in food science/food technology/food engineering.

Knowledge for product development in the company can be acquired from outside R&D. It is important to identify the direct access to knowledge and also the indirect access through information as shown in Fig. 4.1. Many government agencies provide information in reports, databases and published papers, which can be developed into useful knowledge by the company. This information can be stored in libraries or other information storage facilities and on the Internet. But the company can also work directly with government research agencies, consultants, ingredients/equipment suppliers, and consumer research companies, to develop specific knowledge for the company.

It is important to recognise the science and technology information tracks so that they can be tapped into as problems arise in product development. Research in industry is focused primarily on advancing technology to fulfil changing consumers' needs, whereas in universities and in many research institutes it is focused primarily on advancing either science or generic technology (Betz, 1998). In the science track, the knowledge is published in peer-reviewed journals and is eventually summarised in textbooks and taught to students, although with modern funding in universities a significant amount of the knowledge is not published but is transferred directly and exclusively to the sponsors of the research. From an understanding of the current state of scientific knowledge, researchers in engineering and technology advance the knowledge in their disciplines by research on the basics of the technologies. This basic technological knowledge is published and taught to the next generation of engineers and technologists, and transmitted to their counterparts in industry in conferences and journals. In the early years of a new technology, a company works mostly with knowledge discovered during the industrial development. Gradually technological knowledge sources are built up and these can be used in later development projects. A combined knowledge of the food system, and in particular the company's segment of it, is built up over the years by the company's R&D and its experience in marketing, production, distribution and engineering. This is the basis for future product development.

The company also looks for knowledge from its competitors, by studying their actions and products in the marketplace and their production, raw materials and processing. Most industries work from a similar technological base; 80% of the knowledge is known by everyone, maybe even more. In product development it is the extra 10–20% knowledge that makes the competitive edge, but the company also needs to have the capability to use fully the basic knowledge.

The company is creating knowledge along the whole system from the initial R&D to the final outcomes of the product in the market (Quinn, 1992) as shown in Fig. 4.2. Knowledge is being created and then extended in the next stage

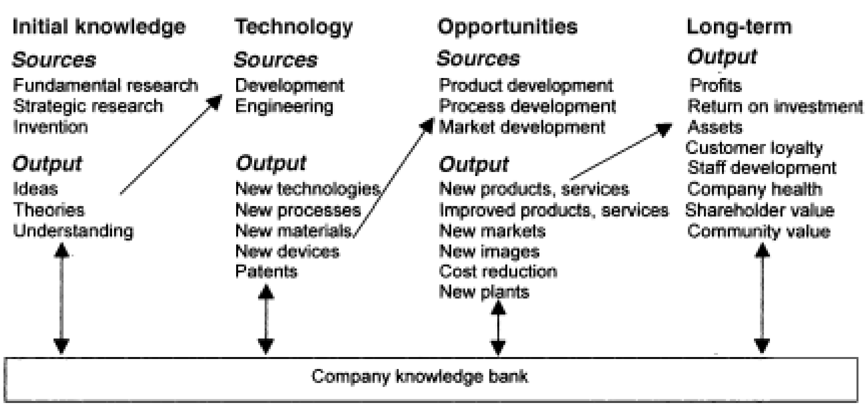


Fig. 4.2 Movement of knowledge through the company (Source: After Quinn, 1992).

where more knowledge is created. Even at the final stages where the new development has become a commercial reality, there is still knowledge being created about the product, production and marketing. Although there is a clear movement of knowledge from one stage to the next, there also needs to be interconnecting communications of knowledge between all stages so that the new knowledge is shared and the total company knowledge grows. There is also a need to evaluate the use and creation of knowledge in product development; usually the embodied knowledge, particularly the product and its success in the marketplace, is used as the indicator of the knowledge achieved in the project.

Companies have difficulty in relating the knowledge created by fundamental research to the company's final profit. But fundamental research can be evaluated on the new knowledge and understanding that is passed on to product development. Just ask the product developers what it would cost them in the long term if the fundamental or the strategic research disappeared; or if strategic research improved its performance what extra value would that give to development! In the food industry in the past 20 years, R&D has tended to be either dropped or reduced – one wonders how the company valued this asset, and how much it cost them to buy in this knowledge in the following years, and how many opportunities were lost. It is important that each knowledge-creating area is evaluated regularly to find which area is performing in creating knowledge that leads successfully to the long-term goals.

Invention is difficult to place in the knowledge flow because it is based on observation of what is happening maybe in a technology or in the community, unlike science, which is trying to discover new knowledge. Invention is not necessarily limited by the extent of scientific knowledge; inventors rely on their accumulated practical knowledge and their own intuition (Cardwell, 1994). Invention requires some conceptual or imaginative creativity. To make an imagined transformation physically real, it also has to have the necessary technology, knowledge and skills. So it is an idea that has come to its time – the idea may have been imagined a long time before but cannot be made real unless the various factors are present in people's knowledge and skills (Mitcham, 1994). The concept of invention is the opposite of the incremental change. As well as taking place in an individual's mind over a short period, it can develop in a group through time together, but not substantially through systematic design. It is intuitive or even accidental events that lead to invention. The food industry has in the last 60 years been looking for the magical invention of a major new method of food preservation, but it has not come. There have been many improvements in drying, freezing, chilling and heat sterilisation, but there has not been the invention of a completely new method. Atmospheric control has been the one new preservation method that has gradually grown as packaging technology and inert gas production have improved. Although scientists have been studying it for over 60 years, the scientific knowledge has grown very slowly, but it is now expanding in combination with chilling for long-term storage and transport of vegetables, fruit and meat. Other methods, such as irradiation and the use of gases such as methyl bromide, have been used in food preservation, but they are rather blunt instruments that certainly did not fit with the societal environment.

Think break

Consider your company and its sources of knowledge for product development:

1. Identify a new product that has come from an invention inside the company. What knowledge did the company need to bring this invention to a commercial product?
2. Choose a product that is being developed at the present time. Identify the tacit knowledge that was used in the first stage of the product development process, and the people who supplied this tacit knowledge.
3. Choose a product that has been launched. Identify the explicit (codified) knowledge that was used in the final stages of this product commercialisation and launching.
4. Describe how in your company the knowledge created in the product development project is saved as tacit and explicit knowledge for use in future projects. Discuss how the saving of this knowledge might be improved in the future.

4.2 Knowledge management or knowledge navigation?

Technological capabilities in product development consist of the resources needed to generate the technological opportunity and manage the technical change, including skills, knowledge and experience, and the institutional structures and linkages. Technological knowledge is usually the most important. A large part of technological knowledge in product development has a tacit nature, being incorporated in people skills, competencies and organisations. Tacit knowledge is often not codified and is largely company- and indeed often area-specific, and may be difficult to transfer to explicit knowledge. Learning is often the central method for passing tacit knowledge and building it in the product development team.

There is also an ever-increasing bank of explicit knowledge used in food product development, from consumer changes to advancing technology, and it is difficult to find all the appropriate knowledge for a specific project. It is not sufficient just to have storage systems for information; there need to be clear paths to find and assess total knowledge in different areas of the company and indeed outside the company. Knowledge navigation is a better description than knowledge management; knowledge navigation includes the strategic directions for knowledge as well as the knowledge systems. One of the key roles of top management is to create a culture and environment that is conducive to knowledge capture and knowledge sharing. Management leads the company into strategic directions for knowledge.

4.2.1 Strategic directions for knowledge

It is management's role to ensure that there are the technological knowledge and capabilities to fulfil the company's overall innovation strategy and to implement product development strategies for the company. It is important to understand where they have been, where they are at present and where they are going. In the 1990s, there was a spurning of historical knowledge, which ended many times in 'reinventing the wheel'. Today, there is recognition that there is a need to store a reasonable percentage of this knowledge in a codified form for the future, because of the much greater turnover of staff and the loss of tacit knowledge. Total quality management introduced much more recording of production and product quality information. Now improved information systems make it much easier to store and retrieve knowledge of formulations and processing differences. Product formulation is an area where there have been attempts to develop recording systems which can be used in later product development. For example using case-based systems, the records of previous formulations – both successful and unsuccessful – are used as a knowledge source with the product properties and their specifications, which can be retrieved to find a possible formulation for a new product (Rowe, 2000). Over the years, this becomes a valuable source of company explicit knowledge, which can lead also to fundamental knowledge in the specific area of the company. This is taking the tacit knowledge learned by experience and building it into generally available explicit knowledge.

Management needs to ensure that there is the needed knowledge in the company for their product development plans to be carried out. But there is always the question of how much money should be spent on knowledge in the company both in people's minds and in recorded knowledge – how much on people and how much on an information technology system? Then how should this be split between the different stages of the product development project? If one looks at the stages of the product development project and the expenditure of money and man-days (Cooper and Kleinschmidt, 1988) in Fig. 4.3, then we could say that the knowledge created is related to the man-days expended in gaining it. Figure 4.3 shows how the expenditure increases as the project goes to commercialisation, but the proportion of man-days spent was greatest in the product design and testing stage. There is a large capital expenditure in the later stages of the PD Process at the latest stages, but it is interesting that in Cooper and Kleinschmidt's study there was not a related increase in knowledge as epitomised in the time spent by people in the project. Management needs to study the pattern of knowledge creation by people in product development and decide if it is optimal. Management has also to ensure there is sufficient communication in the company to make full use of the present knowledge in the company.

There is always a need to identify the knowledge needed in the future, both short term and in the long term; there may be a need to create new knowledge in the present product development project. In the incremental innovation strategy, this is building a bank of knowledge for future projects. But when innovation is more discontinuous, maybe to a new product platform or a new processing technology, then there is need for a new knowledge base. This can be a difficult

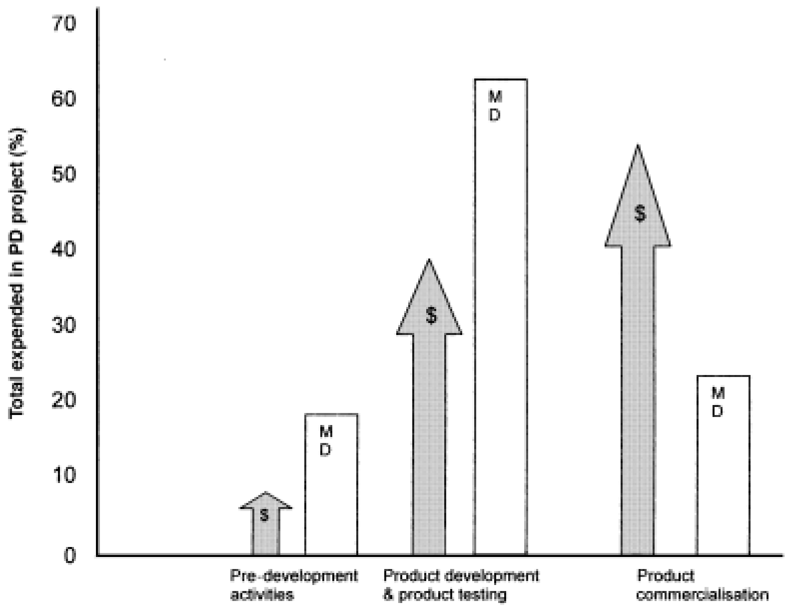


Fig. 4.3 Man-days (MD) and mean expenditures spent in PD Process (Source: Adapted from Cooper and Kleinschmidt, 1988).

and indeed impossible task if management has not been planning ahead. It may be impossible from the present knowledge level in the company, and therefore food companies often fall back on capital investment, buying equipment and knowledge from the equipment manufacturing company.

The management needs a strategic knowledge policy for the company that identifies the knowledge areas and also the dissemination of the knowledge within the company. The communications policy must ensure that the knowledge is not embedded in departments, but can be made available and integrated by the product development team. This again emphasises the need for product development to be integrated throughout the functional areas in the company. The basis for all knowledge is people, and management has to see that people with the necessary knowledge, skills and capabilities are in the product development team, and that they are able to create knowledge in the project as it is needed and communicate this knowledge for future projects. Is management transmitting this to the human resources group and is it prepared to employ people with the necessary skills, and reward them for their skills? Tissen (1999) suggested that these creative, innovative people need to be thought of as highly as soccer players, with high transfer fees and high salaries. Management also needs to provide the information system that selects, collects, integrates and analyses information and also has an interface with the product developers that leads to efficient recovery of the specific information. This is far beyond the information system in many food companies at the present time, but companies should be aiming for it. It is a significant factor that can make product development more effective and efficient.

Another factor that management needs to consider is the direction for the company's knowledge. This grows from the base of present knowledge, which may lead to skewed directions in building up the future knowledge. For example the company can be directed by:

- craftsmen and rely on tacit craft knowledge, knowledge which is based on doing and remembering;
- accountants and rely on financial knowledge;
- engineers and rely on scientifically analysed practical knowledge;
- marketers and rely on social/personal interactions in a marketing situation;
- scientists and rely on scientific logic and method.

There are always several forms of knowledge in the company, but the dominant knowledge gives the direction to the company, and the other knowledge follows it

Box 4.1 Formation of a product strategy

1. Develop sophisticated scenarios for the competitive environment of today and the future.
2. For each of the scenarios, describe the ideal successful companies within the scenario and their attributes, in particular the advantaged and base knowledge incorporated in their products/services and throughout their value chains (advantaged knowledge – knowledge that does or can provide competitive advantage; base knowledge – knowledge internal to a business that may provide short-term advantage, e.g. best practices). Also decide on the depth of each knowledge that is needed.
3. Determine who are the current and potential future knowledge leaders in developing and applying the advantaged and base knowledge elements identified. For your company, identify the specific internal individuals who possess the knowledge. Outside the company, it is best to specify institutions/companies and even individuals who possess the knowledge.
4. Decide where the ideal company should source its knowledge, both internal and external to the company. Decide on the depth of a particular knowledge that should be inside the company and the source for the extra knowledge needed.
5. Choose the ideal company to model your company upon, and develop the business strategy and routes to reach that ideal. Plan how you are going to acquire and maintain people with the necessary knowledge.
6. Establish the effects on shareholder value of the particular area of advantaged knowledge.

Source: From Clarke, 1998, by permission of Research Technology Management.

and often is at a much lower level. This is seldom realised by the directors who sit on Boards of companies and give the knowledge direction that is followed by the executive directors and then the rest of the company. It is important that a wider knowledge direction is recognised and set for the company. The company needs to develop a knowledge strategy as shown in Box 4.1.

Think break

Select four food companies, two manufacturing consumer foods and two processing food ingredients for food manufacturers, with which you are familiar.

1. Decide what are the overall directions for the companies, and then decide what are the major and minor knowledge areas in the company.
2. What are the companies' most important innovations during the last five years?
3. How do these innovations relate to their knowledge areas?
4. Now looking at your own company, identify the different knowledge areas and discuss firstly the importance of each and then the use of them. Scale the importance and use on the following scales:

   Not important____________________________________Very important
   Seldom used____________________________________Always used

5. Identify the future innovation directions of the company and decide what knowledge will be needed for these future innovations.

4.2.2 Knowledge systems

There is a need to select a system for knowledge, but what is it to be? The first general concept is a combination of the traditional and the new; but the short answer is that the Western ideology of knowledge may prevent this. One of the knowledge bases for processing technology is science; however, Western science as well as not appreciating technology even finds it hard to tolerate technology that it can neither comprehend nor appropriate (Marglin, 1996). This has presented problems in food knowledge because it has led to definitions of food science and food technology as being different, with one thought of as superior knowledge to the other. This is quite basic to Western thought, with ideas of *episteme* and *techne*:

- *episteme* is knowledge based on logical deduction from self-evident first principles;
- *techne* reveals itself only through practice, its theory being implicit and usually available to practitioners.

Techne is embodied as well as embedded in a local social, cultural and historical context (Apfell-Marglin, 1996). *Techne* knowledge is geared to creation and discovery rather than to verification; it recognises a variety of avenues to knowledge; the test of knowledge is practical efficacy. This knowledge split between *episteme* and *techne* was epitomised in food industry knowledge by the craftsman and the food scientist.

But now, knowledge and action are increasingly based on a combination, a synthesis between *episteme* and *techne*. In the food industry it will be the ability to synthesise a method of product development that combines logical thought with action in building knowledge, so that greater knowledge develops and therefore more advanced products. As Apfell-Marglin (1996) noted 'a particular system has its own theory of knowledge, its rules for acquiring and sharing knowledge, its own distinctive ways for changing the content of what counts as knowledge; and finally its own rules of governance, both among insiders and between insiders and outsiders.' Food industry management can do this by making strong access links into the universities and the research centres, and at the same time providing an atmosphere and organisation to create new knowledge. This again needs the adoption of total technology as a basis for company management and in particular innovation management. The dominance of one function has led to a lack of true development in the food industry.

- The domination of the financial knowledge system led to cost cutting, staff redundancy and mergers, which in the end decreased the total knowledge in the company and the industry.
- The domination of the marketing knowledge system led to deterioration in technical ability and plant.
- The domination of the production knowledge system led to deterioration in the consumer/product relationship and loss of competitive strengths.

For successful product innovation, there is a need today for a knowledge system which integrates and does not allow domination; which accepts and uses the logical thought and principles of science but actively creates knowledge by venturing into unknown futures. Product development is a process that is built on this type of knowledge system as shown in Fig. 4.4.

The knowledge capabilities in product development are related to all the functions in the company, R&D, intellectual property, engineering, purchasing, quality assurance, rapid testing of the product, distribution system, personnel, environmental relations, and so on. Everything and everyone need to be included as shown in Box 4.2. This is an example of both collecting the company's information and of using it to develop new knowledge, new products and new restaurants.

The knowledge system relies mainly on three human factors: cognitive understandings, learned skills and deeply held beliefs of individuals (Quinn, 1992). Quinn chose the term cognitive understanding instead of knowledge to emphasise that what is needed is a perceptive and understanding knowledge. The PD team needs the know-how for an activity, and also needs the skills to perform the activity. But if there is a lack of self-belief, will or motivation to succeed, then the activity may be completed at a lower level and in a longer time. The company has to have the know-how to solve the product development problems, the skills to use

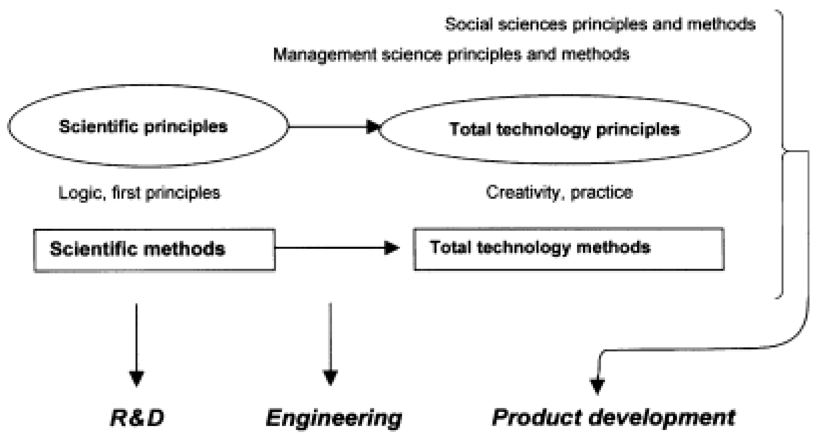


Fig. 4.4 Science, engineering and total technology.

this know-how and develop the commercial product, and the belief in the product that motivates them to lead the project to product success. Bringing the three together in people leads to outstanding product designers, process engineers, marketers, production staff and financial experts. Bringing the three together in the company Board and in management leads to an outstanding company. The knowledge system for product development depends less on providing capital and physical resources (although they are still needed) than on finding and educating people to develop the knowledge, skills and attitudes they need for product development in general and for specific tasks in product development.

The knowledge system also needs to share knowledge, and to provide structures such as teams to encourage this sharing. Knowledge grows when shared, some people would say exponentially. The company knowledge base increases with time, the next project starting from a higher knowledge base than the previous project. Sharing is an excellent way to create knowledge; people with different knowledge and skills, talking, interacting and working together rub ideas off each other so that original ideas form. People with specialised knowledge need to be educated to share their knowledge with other people, so that they can increase their own knowledge as well as blend in with other specialist knowledge in the company. One of the great hurdles to knowledge growth is knowledge snobbery, one type of people thinking they are superior to others. In a commercial company, which has to deliver successful technology – products, markets and production – it can be a complete disaster. The aim for success is interwoven, forward-looking knowledge. It must be realised that there is a certain limit to the amount of knowledge that people can carry; some can work only in one area, others may manage two areas, the outstanding people three or four. Information overload can swamp people. But everyone can integrate knowledge, if it is in a basic form without speciality details and jargon.

It is important to identify what are the key knowledge areas to have in the company and concentrate on them. Knowledge can be bought from outside to

Box 4.2 Integration in food service development

General Mills Restaurant Group (GMR) approaches technology in the broadest possible terms.

At the strategic level

It uses its databases with conceptual mapping techniques to define precise unserved needs in the away-from-home eating market. GMR's technologies can determine not just whether people want Italian food, but whether they want Italian fast food, dinner-house, mid-priced or up-market; combinations of foods, prices and values.

- Concept development with inside and external chefs and restaurateurs.
- Concept evaluation with models from databases to select type and situation of outlet.
- Optimum sites and architectural designs using 'other' technologies.
- Optimise site development and construction using PERT (performance evaluation and review technique) and other operations research tools.

At the operations level

By mixing and matching very detailed performance data from its own operations and laboratory analyses, GMR can select the best individual pieces and combinations of kitchen equipment to use in light of investment considerations, performance characteristics, operating costs, repair needs, flexibility for different menus, systems fit with other pieces of equipment.

- Facility layout using own experience and data.
- Equipment design using its laboratory data and equipment manufacturers.
- Raw material sources and availability identified from databases and satellite earth-sensing systems.
- Raw material preparation and handling with suppliers, for maximum market value and minimum cost.
- Restaurants functioning with integrated electronic point-of-sale and operations management system directly connected to headquarter's computers. Satisfaction tracking surveys with customers.
- Monitoring and analysis of quality, sales and operations.

Source: After Quinn, 1992.

fill the gaps; either by employing new people with the knowledge, or contracting out to consultants and other companies. The choice depends on the long-term future plans of the company. If the problem is not likely to be met again, at least far into the future, then it is the time to bring in the consultant; if it is going to be a major area for the company, then it is more efficient to bring the knowledge into the company. At all times, there must be sufficient integrated base knowledge inside the company to understand the knowledge needs and to make the decisions on where the necessary knowledge can be found.

Think break

1. Cognitive understanding (knowledge), learned skills and deeply held beliefs of individuals are identified as important for successin product development. For each of the four stages of the product development process, identify what you think are the most important cognitive understandings, learned skills and deeply held beliefs.
2. Knowledge sharing is important for growing knowledge in a company. Identify areas in product development where knowledge is shared in your company and areas where it is not shared. How could you extend knowledge sharing in your company?

4.3 Necessary knowledge for product development

To change the product idea concept into a new product, knowledge of the raw materials, processing, product qualities, consumer/product reactions, marketing and the general environment is needed, as shown in Fig. 4.5. These knowledge areas are all interacting. For example, processing knowledge affects the knowledge of raw materials; if low temperature drying were chosen, the microbiological quality of the raw materials must be carefully controlled to ensure safety in the product. So it is not a case of seeking knowledge specifically in one area, but interacting this with knowledge in another area. The consumer may wish to have the liquid in a bottle, but only cartons can be used in the processing line, so one has to discover how the consumer reacts to a carton and how they would accept cartons. The descriptions of

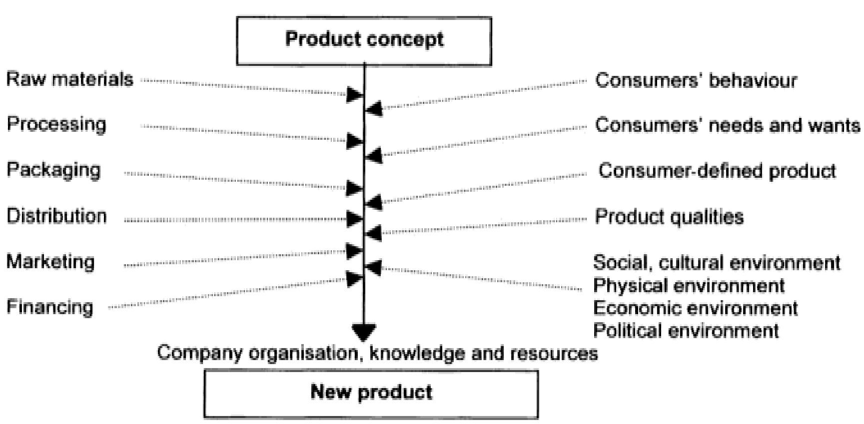


Fig. 4.5 Knowledge for conversion of product concept to new product.

the product by the consumer have to be changed into quantitative terms in the product qualities; so there is need for knowledge of the consumer's needs and wants on product attributes and also the methods of measuring these attributes. Central to the activities are the two important areas of the consumer and the technology, but there also needs to be knowledge of the environment. Knowledge of the consumer is detailed in Chapter 5.

4.3.1 Technological knowledge

The general knowledge areas important in technology are (Gawith, 1999):

- knowledge of science, mathematics, social sciences;
- knowledge of techniques, testing, modelling, interviewing, manipulating tools, materials and data;
- knowledge of procedures and processes;
- knowledge of generic concepts and ways of thinking.

In product development they can be grouped under products, raw materials, processing, packaging, distribution and marketing as shown in Table 4.3. This shows the wide variety of knowledge that is needed in bringing the product from the concept to the actual product.

For example, consider the development of a protein food. Consumers want a high-protein food, but what does that mean in percentage of protein? They want a red colour but what is that measured on a colorimeter? They want a crisp texture but what is that measured on a texture meter? If the protein content is to be 15%, then it is necessary to know the protein content of the raw materials; if the colour has to be a certain red, then the red pigment in the raw materials needs to be identified and measured. There may also be a need for a certain protein; in breadmaking, there is a minimum amount of wheat gluten to give the structure of the leavened bread; in sausage making, only a certain amount of offal can be used because of its poor water-holding capacity. So the type of protein, the quantity and sometimes the amino acid composition need to be specified in the product and the raw materials. Different processing conditions will denature the protein to different extents; limits are set on the processing variables so that the product has the desired nutritional properties. Browning, the combination of amino acids and simple carbohydrates, decreases the value of the protein so the packaging needs to stop absorption of water and also there need to be limits set on the storage conditions of temperature and humidity. If the product has achieved a certain nutritional protein value, then this knowledge is supplied to the consumer in promotion and public relations. So finally the consumer receives the product, but needs to know how to handle it so that the final food eaten has the protein nutritional effect that the consumers desired.

This example gives some idea of the knowledge from many disciplines, which has to be integrated in product development. If there are many specialists from different areas, the problem is how to combine their knowledge throughout the project. If there are not many people in the company, the problem is how to fill the gaps in the knowledge.

Table 4.3 Types of technological knowledge in product development

Product qualities
Properties: appearance, size, shape, sensory; nutritional, compositional
Use: safety, ergonomics, preparation and serving, eating
Product limits: legal, price

Raw materials
Properties: type, production method, chemical composition, traces of pesticides and herbicides, toxicity, nutritional composition, sensory and physical properties, microbiological counts
Price: price range, relationship of price to quality
Raw material limits: caused by processing needs, product structure needs, other product properties, quantity available; minimum and maximum needed in the product, effect of processing on the raw material, legal limits on use

Processing
Unit operations: heating, pasteurisation, sterilisation, freezing, chilling, drying, mixing, tumbling, pumping, conveying, packing
Unit processes: gelatinisation, hydrolysis, browning, denaturation, oxidation, death of microorganisms, growth of microorganisms, vitamin destruction
Processing variables: temperature, water activity, atmosphere, time
Costs: raw materials, processing, factory, distribution, marketing and administration
Processing limits: temperature range, rate of increase/decrease in temperature, viscosity range, mixing speed range, basic equipment design

Packaging
Packaging materials: film, cardboard, metal, glass
Packaging type: bottle, carton, pottle, can, sachet
Packaging method: hand, continuous, automatic, aseptic
Packaging limits: shelf life, protection

Distribution
Transport: roads, rail, sea, air
Transport conditions: time, temperature, humidity, vibration, handling, costs
Storage: ambient, chilled, frozen, atmosphere controlled
Storage conditions: time, temperature, humidity, atmosphere, handling, costs
Distribution limits: shelf life; protection from contamination, breakage, deterioration; available transport and storage; timing of transport; costs

Marketing
Market channel: product flow through market channel, people and organisations (retail outlets, wholesalers, agents, ingredient suppliers)
Market channel requirements: size, weight, availability, price, display and information
Promotion: media advertising, public relations, in-store promotions, free samples, competitions
Promotion needs: create awareness, encourage to buy, education, creating a product image
Pricing: customers' product value, costs, price range, price discounts, competitive pricing
Marketing limits: channel availability, channel controls, competitive actions, promotion availability and costs, customer needs and attitudes, legal controls on marketing.

Think break

1. For the product design and process development of peanut butter slices in a vacuum pack, similar to cheese slices, decide on the knowledge needed for product qualities, raw materials, processing and packaging. How much of this knowledge is already available, and what would need to be created in the product development project?
2. Three different varieties of mangoes have been selected for export to Japan from Thailand (see Section 7.2). What knowledge would be needed for packaging, distributing and marketing in Japan? How would you conduct the development to either find or create this knowledge?
3. Packaging is an area where there has to be close collaboration of food manufacturer and packaging company. It is recognised that for the food manufacturer (Belcher, 1999):
   (a) purchasing wants easily exchangeable packaging that can be quickly delivered by several companies,
   (b) marketing wants a package that is a communication vehicle and that can convey an image,
   (c) legal department wants a package that definitely protects the product from contamination, and is deemed a safe product for the consumer so as not to incur any liability on the company,
   (d) the food technologist is interested in the package for what it can do to protect the product quality, safety and can enhance the new technologies that are being employed.

Discuss how the packaging company can deliver this wide variety of knowledge to the manufacturer and create new knowledge with the manufacturer.

4.3.2 Knowledge of the environment

Knowledge of the social, cultural, physical, economic and political environments is very important in product development, but is a massive task even in the largest companies who can have staff devoting their time to it. Fortunately many of the social and cultural changes are slow moving so there is time to predict where they are going. But of course political changes can be quite fast, especially where revolutions occur. Where does information come from – people, media, magazines, reports, journals and the Internet? How are we to convert it to useful knowledge in product development?

Information in many of these environmental changes does spread around the world quickly because of modern communication, but often it is in the 'communication bites' beloved of the media, which do not tell the whole story and in some cases distort the information. The large companies have staff placed in close proximity to parliaments and politicians so that they are not only actively looking for information but are indeed influencing the trends. But this is often a long way from the person managing product development on a daily basis, so one can find two opposing directions in the same company. For example, the product developer with close customer and retailer relationships in Europe may be designing natural, organic products, while the political lobbying staff may be trying to influence politicians to accept genetic engineering.

There are many economic reports and physical climatic reports around the world; it is not difficult to find information of possible increases in economic status of peoples, which will lead to a different food choice, and on effect of climate change on food choice – less hot soup and more ice cream. Economic change is now occurring in China and it is not difficult for the food companies to predict the food changes and the possible products that can be developed for this market. There are many predictions of climate changes, which may not be precisely reliable on timing, but still give the direction of change.

So how is this information on environmental changes developed into knowledge in product development? Many of the overall changes are incorporated in developing the business strategy, innovation strategy and therefore the product development strategy. So these overall changes are incorporated into the product development planning. But there are specific effects on the product development project and these must be carefully noted in planning the important decisions at each stage, so that the team can find the knowledge to meet these decisions. There need to be people in product development teams who are outward-looking and aware of what is happening in the environment and have the ability to bring this into the product development programme and projects.

4.3.3 Sources of knowledge

In product development, there is a continuous development of knowledge:

past knowledge **---** present knowledge **---** future knowledge

There is recognition of the past knowledge which needs to be kept either in a company's memory or in its databases – it is unrewarding to keep 're-inventing the wheel'. One must not cling to the old knowledge as sacrosanct, but as a building base for the present and the future. At the beginning of the product development project, one is judging the knowledge available at present and assessing this against the knowledge required throughout the project.

Knowledge available

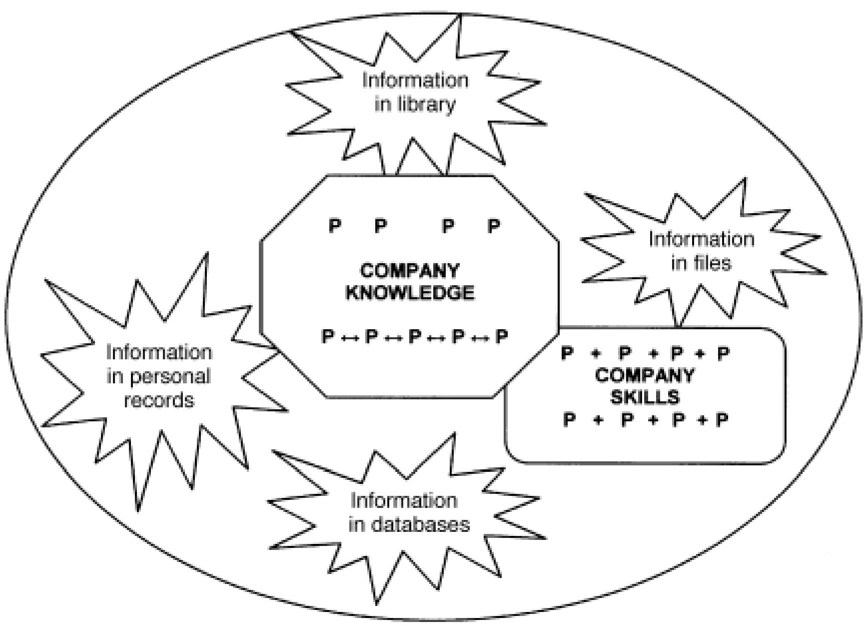
Knowledge required

Knowledge to be created

The **knowledge already inside the company** is the first type to consider. Basically this is inside the heads of individuals, but together it becomes the total company knowledge if the knowledge is shared. In every company, there are individuals and groups who may not share knowledge easily so that a system has to be set up to ensure sharing of the combined company knowledge for a project. In incremental product development, as much as 90% of the knowledge required is already available inside the company if there is knowledge sharing. In product innovation, the present knowledge may be as little as 40% of the knowledge required – if any less, then warning bells should sound for the project.

Knowledge can be created from information inside the company – in the files, databases, library and information system. An important information source within the company is staff personal records; people often record detailed information, which is condensed in reports or even not reported. Some information may not have been significant in one project, but is in a later project. Some companies try to collect this into a central computer system, but even then it may be difficult to retrieve the information without the individual's interpretation of it. Within the company it is always difficult to balance the costs and usefulness of stored information. Between the two extremes of 'wiping the slate clean' and 'paralysis by information and analysis', there is a balance for every company that depends on the knowledge level of their staff and the costs of storing information. One persistent problem is to ensure systems are in place to record all significant data and events.

The company's capabilities or expertise can be described as a combination of the company knowledge, the company skills and the availability and relevance of the company information, as shown in Fig. 4.6. The collective body of



P is personal knowledge, in people's heads; and personal skills.

Fig. 4.6 Knowledge and information in the company.

company knowledge (core memory) plus the company's skills (core competencies), plus the information system within the company combine to form the company's core capabilities. The knowledge can be the separate knowledge of people (P), but much more important is interactive knowledge between people (P +-- P +-- P +-- P). In the case of company skills it is an additive effect of individual skills (P + P + P + P); in the company, people always have to work together and must not work separately. The information system may be separate sources or combined on a network in an information system.

Fleck (1998) identified expertise as knowledge (philosophy, technical specialities), power (sociology) and tradability (economics). Power is part of the organisational structure, within the company but also in professional and other organisations, and knowledge is seen as embodying social relations within which power is mediated and reproduced. There is no question that power in the company can influence the direction of knowledge in product development, and also the resources for that knowledge, whether the power is held in finance, marketing, production or top management. Tradability is determining if a particular knowledge is better at carrying out a task than a competing knowledge. This is often an argument in industry against using more complex knowledge – will the product development be more efficient and effective or just more costly? Power and tradability emphasise that expertise is not 'pure' in a company; the selection of knowledge is influenced by the people with and without power inside and outside the company, and its marketability both internally and externally. Technological knowledge is often influenced by both of these factors. Communication is also important for the company's capabilities (Court, 1997), and this has been shown in Fig. 4.6 by interrelating the people P +-- P +-- P, but individuals, P, have also been shown who are in the company's capabilities but are not interrelating.

It is important to differentiate between information and knowledge, although there are certainly grey areas where they mix. One can consider them as weighted:

$$\text{Data} = d$$
$$\text{Information} = d \times c = \text{data} \times \text{content}$$
$$\text{Knowledge} = d \times c \times e = \text{information x experience}$$

Databases have been shown as a particular type of information. There is a grey area between databases and information, but data are usually considered the raw facts, information is data that have been worked on to give a meaning that can be understood (Court, 1997). Usually databases are the lists of product sales figures or the demographic information on population. There needs to be recognition that information only becomes active knowledge in product development if it is linked either with past experience or experience in the present PD project.

Sources external to the company are important for knowledge not available in the company. Depending on the state of the company's core capabilities, it is important that necessary additional knowledge and skills are transferred from external sources to the company. In particular the knowledge of customers and suppliers provides important sources, where there is close contact between the company and the outside sources of knowledge. There is knowledge and information outside the company that can be used to fill the gaps in the knowledge for specific projects. This is illustrated in Fig. 4.7.

The place of consultants in the knowledge/information spectrum is varied; there can certainly be skills transferred, but unless the consultant is intertwined in the company, only information can be transferred and not knowledge. This is similar for universities and research institutes; skills and information can be transferred, but knowledge can only be directly used if it is relevant specifically to the company. Company staff and company management need to go outside the company to identify new tacit knowledge from consumers, customers, or scientific and technological centres. Many ideas can come from outside the company but there needs to be the internal tacit knowledge to recognise them and relate them to the company product development (Lenzner and Johnson, 1997). It is not enough to read the information coming into the company, it may be out of date and not easily related to the company, and so its effective incorporation has to be organised and ensured.

4.3.4 Sources of information

The sources of information are both internal and external to the company. They can be grouped as tacit, mix of tacit and explicit, and explicit sources.

- Tacit – company staff, personal experience.
- Mix of tacit and explicit – business consultants, customers, exhibitions/trade material/conferences, family and friends, government agencies, other companies and competitors, suppliers/sales representatives, trade associations/professional bodies.
- Explicit sources – in-house databases/reports, information brokers, libraries, media, on-line sources, patent information, trade journals.

In the Italian industry, Evangelista (1999) showed that for technological information, the internal departments were the most important channels for information into the manufacturing companies as shown in Table 4.4. Internal sources were not as important in the service companies as in manufacturing. Among the external sources for information, clients, customers, suppliers of equipment, materials and components were the most common sources. Information flowed from both the upstream and downstream user/supplier interactions. Consultants were more important in the service industries than in the manufacturing companies. Other sources – universities and higher educational institutes, private research institutes, public research institutes, agencies for technological transfer, patents, licences and other external sources – were very important to less than 5% of the companies.

Campbell (1999) also found in New Zealand that customers and company staff were the important and most used sources for information. The heavily used sources were personal experience, customers, company staff and in-house sources; the moderately used sources were exhibitions/conferences, other

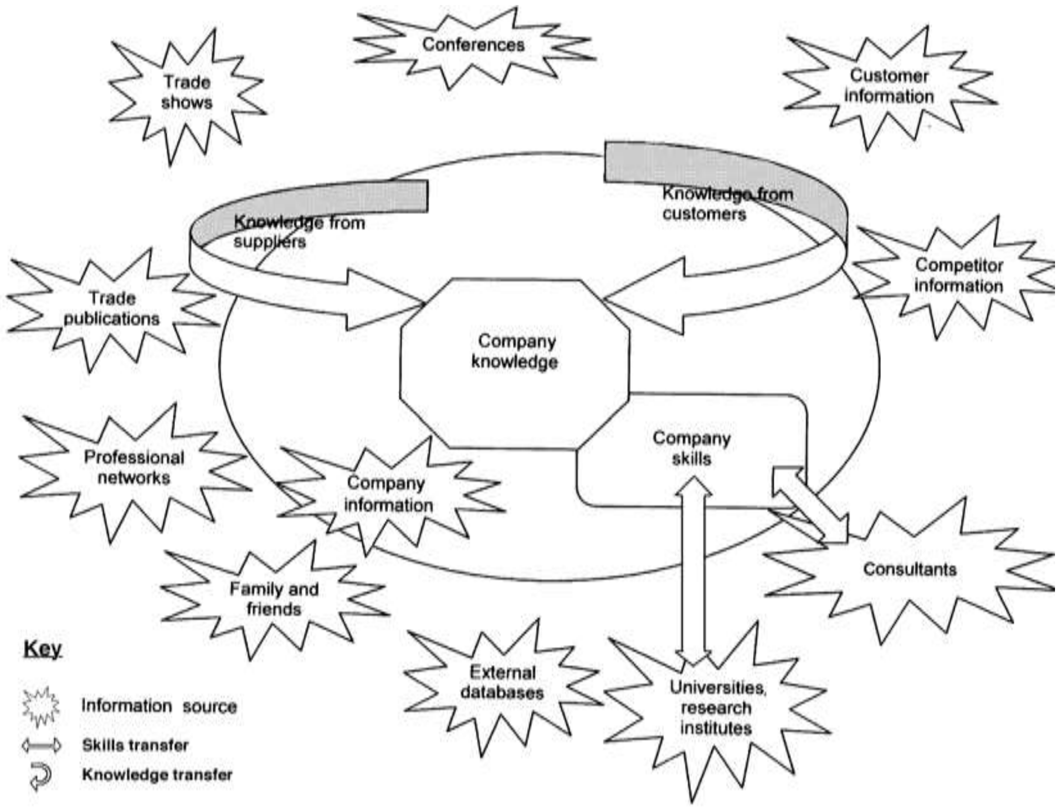


Fig. 4.7 Knowledge and information from outside the company.

Table 4.4 Sources of technological information in manufacturing and services

	Innovating firms for which the source is very important	
Sources	Manufacturing % of total (rank)	Services % of total (rank)
Internal sources (Production/delivery, R&D, marketing department)	63 (1)	37 (1)
External sources		
Clients or customers	44 (2)	34 (2)
Suppliers of equipment and components	36 (3)	30 (3)
Fairs and exhibitions	33 (4)	14 (7)
Competitors	23 (5)	21 (5)
Consultancy firms	15 (6)	27 (4)
Conferences, seminars, spec. journals, etc.	13 (7)	17 (6)

Source: From Evangelista, 1999, by permission of Rinaldo Evangelista and Edward Elgar Publishing Ltd.

companies, suppliers and trade journals. Campbell also enquired if the sources were tacit or explicit. Of the heavily used sources, personal experience and company staff were tacit, customers were tacit and explicit, in-house sources were explicit. The moderately used sources, which were external to the company, were a mixture of tacit and explicit knowledge. Most of the infrequently used sources were explicit, but some professional bodies, business consultants and government agencies provided a tacit component.

Campbell found that highly innovative companies used information more than the least innovative companies, as shown in Table 4.5. The sources where there was no real difference between the three groups were professional bodies, media, trade journals, information brokers and in-house sources; apart from trade journals and in-house sources, these were infrequently used. Overall the highly innovative companies used a greater range of information sources in relation to their product development activities. The highly innovative and moderately innovative companies made use of both formal and informal acquisition methods, the least innovative companies were more likely to gather information informally. The moderately innovative companies tended to use more formal information acquisition methods than the highly innovative companies, both internally and externally.

In looking at the stages in product development, Campbell found differences between the three stages: pre-development analysis, product design and testing, product commercialisation as shown in Table 4.6. There was a surprisingly low use of external information sources. In the pre-development stage, only personal experience for initial screening, and customers for preliminary market analysis, were used by over 80% of the companies. Customers in initial screening and detailed market research, and personal experience in financial feasibility, were

Table 4.5 Information usage for product development

	Companies					
	Highly innovative		Moderately innovative		Least innovative	
Source	Use	Importance	Use	Importance	Use	Importance
Customers	4.3*	4.7[t]	3.7	4.9	3.9	4.3
Company staff	4.0	4.2	3.5	4.1	3.3	3.5
Suppliers	3.5	3.6	2.5	3.3	2.5	3.0
Exhibitions/ conferences	3.3	3.6	3.0	3.5	2.4	2.6
Other companies	3.2	3.8	3.2	3.7	2.2	2.5
Business consultants	2.6	2.5	2.5	3.0	1.7	2.6
Family and friends	2.4	2.4	2.0	2.4	1.9	2.2
Libraries	2.0	2.2	2.3	2.8	1.7	2.1
Govt agencies	1.9	2.5	1.9	3.1	1.5	2.2
Patent information	1.8	2.1	2.6	3.6	1.9	2.0

* Use scale 1 = not at all to 5 = all the time
[t] Importance scale 1 = not important to 5 = vitally important.

Source: From Campbell, 1999.

used by over 70% of the companies. In product design and testing, only personal experience in prototype design and detailed design, company staff in trial production, and customers in test marketing, were used by over 70% of the companies. In product commercialisation, the use of information was the lowest of the three stages. Only company staff and customers in production start-up, and customers in market launch, were used by over 70% of the companies. Overall in product development, highly tacit information transfer was used. Only customers'

Table 4.6 Information sources in three stages of product development

	Percentage of companies		
Sources	Pre-development analysis	Product design and testing	Product commercialisation
Personal experience	64	57	44
Customers	57	46	42
Company staff	44	57	48
In-house sources	43	38	32
Other companies	30	–	–
Suppliers	28	24	–
Business consultants	19	–	–
Exhibition/conference	–	–	17

Source: From Campbell, 1999.

information incorporated an explicit content. New Zealand companies are small by international standards, so some of these uses of information may not be true for large multinational companies. But in product development, there does appear to be a strong reliance on tacit information and less on explicit information.

Think break

1. List the information sources used by your company in product development. Which sources give you vital information, useful information, interesting information, useless information? Would you drop some of these information sources? Do you need to include other information sources?
2. Because of the increasing volume of information, companies have set up systems based on information technology to receive, store and distribute information to the various functional departments, R&D, engineering and product development (Graef, 1998). Describe the important knowledge areas to be included in an information system for product development. What are the important factors to be considered in building an information system as a basis for effective and efficient product development?

4.4 Tacit knowledge in product development

Tacit knowledge is the opposite of explicit knowledge, which is knowledge that can be expressed in words or numbers, in a formal, systematic language, and easily stored and communicated. Tacit knowledge is much more difficult to define (Madhaven and Grover, 1998). It is essentially personal knowledge and therefore is communicated person to person or within a group of people (Nonaka *et al*., 1996). Tacit knowledge in the product development team and the company is a combination and reinforcement of the many individuals' tacit knowledge caused by their interactions. Madhaven and Grover (1998) called this *embedded knowledge* in product development. Evangelista (1999) combined the tacit and explicit knowledge in the group and called it *disembodied technology*. The results of using disembodied knowledge is *embodied knowledge*, in this case the product and the other outcomes of the product development. So knowledge is brought into the product development project, knowledge is generated as the project progresses, and finally the knowledge passes from the project as a new product, production specifications, marketing strategy, financial predictions. This knowledge is not only used in the production and marketing of the product, but can be stored for future projects – either as tacit knowledge in people's heads or preferably stored as an explicit knowledge base.

Often tacit knowledge is specific to a context or area; for example some product developers have tacit knowledge of consumers, products and processes, but may have no tacit knowledge of product testing techniques or of process reactions and would need to rely on explicit knowledge in books and manuals. An important tacit knowledge is the understanding of the defining company situation: where the company is, what it wants to achieve and what are its restrictions/limits on product development, and how does it want to achieve product success.

4.4.1 Individual knowledge in product development

In the product development project, the team therefore is relying on its tacit knowledge augmented with explicit knowledge to provide the required knowledge for the project. Sometimes the project starts with only the tacit knowledge of the team members and further knowledge is generated in the project. This often happens in the small company which lacks information sources, but the larger companies can also do this if there is a perceived need for a fast start to development. Under these circumstances, product success is very dependent on the tacit knowledge and the creative ability of individuals.

Product development is dependent on the dynamics of people and their networks. The individual in product development has knowledge developed from education and experience, but they are also involved in knowledge networks that may be in professional organisations, industry groups, company staff, customers and suppliers. So the individual is dynamically exchanging knowledge while also building up their own knowledge base. Very often, the relevant knowledge for the product development project is general knowledge in this particular group or even in a wider society (Senker, 1998), and only the 10–20% created is really new knowledge. Companies who have great secrecy barriers are sometimes losing this general knowledge and are making knowledge creation more difficult for themselves.

Very often there are individuals in companies who because of their strong connections with external sources are able to gather information that is both relevant and up to date. They may be thought of as information gatekeepers. With their understanding of internal needs and communication systems, they can translate this information into a form that is useful to the organisation (MacDonald and William, 1993). These information gatekeepers can be very useful in product development. Information gatekeepers can also be important within the company, transferring information between groups and translating the information into knowledge for the project.

It is important that the company supports creative individuals, and also provides them with the environment to create knowledge. Creative people are not always the easiest to manage in the traditional power-down method and organisational structure. In some cultures such as in Scandinavia, they are given an important status and given the resources to work together. Scandinavians often wonder why, in American and Canadian research to improve product development, communication is identified as difficult to achieve; they communicate all the time!

Every person in the company can contribute tacit knowledge to product development. Product development is re-creating the company, in a small way or even dramatically, therefore all staff are involved, as also are the customers. It is important in recruiting not to have closed minds, for example recruiting only from certain universities; the company will have too many people with the same way of thinking and not be able to create and tap the necessary new knowledge. A variety of knowledge, skills and motivations are required. And it needs to be combined with experience. There is a need to have a combination of people who have built up their experience in the company and others who have outside experience in the food industry or even in another industry. People with tacit knowledge from other companies will bring new tacit knowledge into the company, which can revitalise the tacit knowledge in the company.

4.4.2 Using tacit and explicit knowledge in product development

Sometimes tacit knowledge has been defined as knowledge from experience that cannot be explained, but this is not usually true in product development except for very simplistic product design. Product development is essentially problem solving, and therefore basic principles are often combined with the results of experience to find solutions. But essentially product development is a defined process, which can be written down in explicit knowledge; as can many of the activities, techniques and decision making. The tacit knowledge is often used to choose the activities and maybe the techniques that can give the necessary outcomes for the decision making. The skills for the techniques are often explicit, being taught and written down in manuals and textbooks. But they may not rely on a thorough understanding of the scientific principles involved, and some would say that they are therefore tacit knowledge. In the food industry, this is a significant point for discussion. The tacit knowledge of the craftsman who could feel bread dough and say it was at optimum fermentation, led to the tacit knowledge of the technician who tests the dough with an empirical instrument that states it is correct for baking. But is the explicit knowledge on bread dough based on scientific principles? In some ways the consumer and market researchers are further advanced as they are using explicit consumer knowledge based on social science research methods. It is based on statistical analysis and not mathematical models, but is explicit for a certain population. It is the change from tacit knowledge to explicit knowledge, which is important for the future – how far is it necessary to make the change so as to have knowledge capabilities for product development in the future?

Although there is written information on problem solving, this is really one area where tacit knowledge is important. In academic education this tacit knowledge is difficult to achieve, because there is often neither the time nor the resources to allow students to develop problem-solving skills under guidance from people with a great deal of tacit knowledge. Very often one can see the process design and product development projects being dropped or never included in food technology courses. These are two of the areas where problem solving can be taught by experience and advice. Indeed in companies, the acquisition of tacit knowledge to support innovation is a purposive activity of much industrial development, design and testing of prototypes and pilot plant (Senker, 1998). This is illustrated in Fig. 4.8 showing how a barrier that stops an idea moving directly to an innovative product may be overcome by intermediate steps such as making

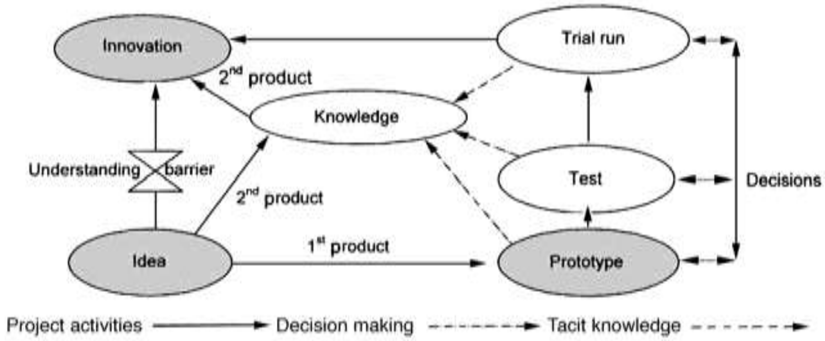


Fig. 4.8 Experience (tacit knowledge) building.

up prototypes and testing them (if needed, with internal recycling), and so establishing sufficient knowledge for implementation of that innovation. When this has been done once or twice new tacit knowledge is created which may enable some or all of the intermediate steps to be cut out in broadly similar innovations.

Technological change has been tacit knowledge-based because it is so much dependent on the knowledge within the company. Especially in incremental changes, 'doing' mostly creates the minor improvements – it is easier to make up the formulations and see if they work than look up scientific information on the processing changes. Innovations are more often based on scientific knowledge, especially in large companies. But they have to be brought into product successes by using the tacit knowledge in combining the product and production, and the product and the consumer. In emerging technologies – biotechnology, advanced engineering ceramics and parallel processing – the knowledge on particular fields is from education and literature, but the tacit knowledge developed in the company, which builds on the formal knowledge, is essential for developing the innovation (Senker, 1998).

The food system uses knowledge for product development in the different parts of the system as shown in Fig. 4.9. In the early stages, it is animal, fish and plant growing or catching, physiology, effects of feeding, nutritional value, sensory properties, uses; this is followed by preservation, cleaning, extraction, treating and packaging. As already noted, the later stages of the food industry divide into two parts – the food processors making food ingredients, which are scale-intensive companies that produce a high proportion of their own process

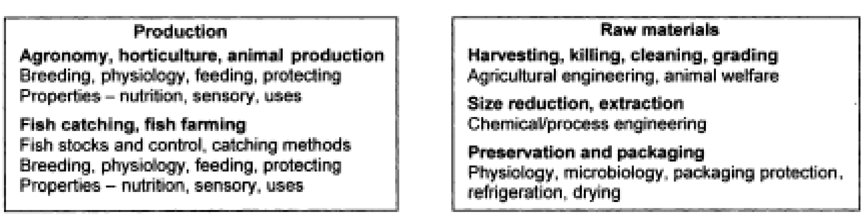


Fig. 4.9 Technological knowledge areas in food production, raw materials.

technology, and the food manufacturers whose product development is largely directed by their ingredient suppliers (Senker, 1998). The food manufacturing companies continue to use tacit knowledge and skills because this is the only way they can cope with the complexity of food systems using the scientific and technological skills that are available to them. The food processors have acquired the scientific and engineering skills of process engineering and are therefore able to use a greater amount of explicit knowledge. But even they are still using tacit knowledge to analyse and plan their product development. Some of the knowledge and skills in the total food system is shown in Fig. 4.9.

In studying engineering designers' use of knowledge and memory in new product development, Court (1997) found that the most prominently accessed information sources were those based upon locally stored information. The engineering designer's personal experience and knowledge, and in particular memory, were constantly used. In many cases, the designer relied solely on recalling items of information and data from their memory rather than spending a large amount of time searching for it. One-third of information accesses were based on memory usage, with higher figures for many individuals. Knowledge formed within memory is of great importance to the engineering designer.

It is important that in product development people not only have skills and knowledge in specific areas but also, through experience, the knowledge and skills to integrate other areas into their particular activities in product development. Someone may be a product designer but they need to be able to integrate both the consumer needs and production needs into their design. People in the product development team also need to have knowledge of the complete product development process and in particular the decisions to be made and the outcomes needed both from their activities and from the activities of the team as whole. There needs to be a shared understanding of the project and its problems on which the team is working, including a shared common language, and a shared organisational memory. The shared memory can be used to solve the present problems, and will affect the outcomes. But of course the whole team can become rather conservative if it has been together for a number of projects and can see only one way to solve problems. Their effectiveness is then reduced. This is important – teams improve with being together but if they are together too long then their product development becomes less effective. On the other hand, one should not keep changing teams too often, as they do not learn to combine their knowledge and develop group knowledge.

The benefits of shared models of the PD Process and the activities in it are true for all projects. The choice of members of a team and its organisation does depend on the level of innovation of the product. For radical innovation there is a greater need for creativity and often for specialist skills, but there is always a need for a wider knowledge of the different activities in product development. The aims of effectiveness and efficiency are always to be remembered:

- **Effectiveness** in a product development team relates to the degree to which the product meets the targeted need of the customer.

- **Efficiency** is defined as a measure of the resources (including time) used for a given output, often compared with some target or ideal (Madhaven and Grover, 1998).

Think break

1. List your tacit knowledge related to product development at the beginning of your working in product development, and then after every five years.
2. What are the most notable areas where your tacit knowledge has grown?
3. How would you help a young person coming into your product development group to develop their tacit knowledge? In which product development areas do you think they most need to develop tacit knowledge for efficient and effective product development?

4.4.3 Changing tacit knowledge into explicit knowledge

Companies are increasingly trying to change the tacit knowledge held in people's heads into recorded or codified knowledge so that this knowledge is less vulnerable and is not lost to the company. This is made possible by the increasing scientific and technological knowledge in the food industry but also by the availability of simple, cheap computer systems such as expert systems linked into internal and external networks. Protection of intellectual knowledge has also pushed this trend; although in the food industry it is often difficult to receive patent protection except for equipment and agricultural plants, the advent of new types of foods in the future, such as nutriceuticals, could lead to more patenting. The other push to more recording of the tacit information was the introduction of quality assurance and management systems, which included careful recording of processes, products and systems.

There is an increasing amount of scientific literature in food science, which could be the basis for innovation. At the present time, it appears extremely varied and much of it is without the focus needed to build it into a new technology, but this explicit knowledge will gradually filter, often via tacit knowledge, into the food industry. As the present food science is adopted into the industry, we can expect greater support for food research and hopefully rapid advancement in food product and processing knowledge. It is a rather chicken-and-egg situation. With knowledge, models of food processes will be accessible that can be used to develop new processes as well as controlling the present processes.

Knowledge can be embodied in theories, equipment use, people and organisations (Fleck, 1998), as shown in Table 4.7. It is useful to recognise these different types of knowledge in a product development team, both the amount of each embodied in the team and also the amount of each needed in a specific project. In the innovation using new knowledge there is often formal knowledge, which has come from research, which has to be developed to fit with

Table 4.7 Components and contexts of knowledge

Key components of knowledge	
Formal knowledge: embodied in codified theories	
Instrumentalities: embodied in tool, equipment use	
Informal knowledge: embodied in verbal interaction	
Contingent knowledge: embodied in a specific context	
Tacit knowledge: embodied in people	
Meta-knowledge: embodied in the organisation	
Contexts of knowledge	
Domains: the areas to which the particular expertise applies	
Situations: assemblage of components, people, domains, etc., at any particular time	
Milieux: the immediate environments in which expertise is exercised	

Source: After Fleck, 1998.

the other types of knowledge which are all fundamental to product development. The informal knowledge is important in product idea generation. Uniting the various types of knowledge with their contexts is one of the important decisions in product development. The instrumentalities, that is equipment knowledge, are important in building up both product testing and process development; but the actual equipment knowledge depends on the situation – equipment available and the expertise of the people to use it. Equipment knowledge also depends on the place of processing and testing – the laboratory or the factory floor, the small company or the large company.

Knowledge can also be divided (Court, 1997) into:

- general knowledge, gained through everyday experiences and general education;
- domain-specific knowledge gained through study and experience within the specific domain that the designer works in;
- procedural knowledge: gained from experience of how to undertake one's task within the enterprise concerned.

Knowledge in product development is needed for the design of the product, production and marketing, but is also needed on the PD Process. There is a standard framework for the PD Process, and the company needs to define the decisions to be made at specific stages. These actually do not differ very much from project to project, but the outcomes needed may vary and the activities vary with the domain in which the product developers are working. The techniques used will vary according to the situations and the milieux.

The knowledge-based innovation usually has the longest lead time of all product development, not only the time span between the emergence of the new knowledge from research but also on long periods before the new technology turns into products, processes and services in the marketplace (Drucker, 1985). It also is usually based on several different kinds of knowledge, which have to be integrated to produce the new technology and the new product. This is why early products sometimes fail, because the product developers may have some of the knowledge but not enough, for example they may know the scientific knowledge but do not have adequate knowledge of consumer behaviour. Food irradiation is an extreme case of this: there was a great deal of scientific and technological research, before anyone thought about the consumer reactions. In the case of microwave ovens, the food industry had done little research on the effects of microwave heating on food ingredients and food, and given little thought to educating the consumers on how to use microwave ovens with their products. It took some time before the food industry caught up with the innovation from another industry. Other examples of lack of holistic knowledge are early freeze-dried foods, and an early attempt to provide unsaturated fats in the meat from ruminant animals, in particular lamb, to give 'healthier' meat. Early freeze-dried products were specific meats, vegetables and fruit, and only when they were incorporated and marketed as convenience meals did they become accepted. The lamb with higher unsaturated fats had health advantages, but tasted like pork and was not acceptable. So it is a case of having all the knowledge threads at the right time, and the milieu of the company that will take the risk, and the domain with all the features to support the knowledge including cost structures.

Think break

In changing tacit knowledge to explicit knowledge, two important storage systems for knowledge and information in the company are the company library and the computerised information technology system.

1. Compare the two systems, listing the advantages and disadvantages of libraries and information technology systems for storing knowledge collected during product development projects.
2. Is it more useful for future projects to have a project's knowledge on a CD in the library than in the information technology system?
3. One of the problems in knowledge/information storage is the age of the material. For how many years should project material be stored? Should resources be made to collect together the information/knowledge from several projects before this time limit?
4. Design a knowledge/information system that will suit your company's need for internal knowledge/information in product development projects.

4.5 Creating knowledge in product development

Creating knowledge is an integral part of product development, and the ability of the individual and the group to create knowledge is important for both effective and efficient product development.

4.5.1 Creating knowledge in the company

Nonaka *et al*. (1996) suggested that knowledge is created in organisations by a process that amplifies the knowledge created by individuals and crystallises it as part of the knowledge system of the organisation. It is hoped that it would not crystallise into a museum piece but act as a dynamic force to move the knowledge system to both encompass wider multidisciplinary knowledge and more detailed explicit knowledge of the present technology. Knowledge can be created within the product development team, the company, and by interaction with the external environment between individuals and groups. This interaction can be between tacit and explicit knowledge, and can cause conversion of knowledge as shown in Table 4.8.

The whole development from the product description to the product design specifications is a conversion of the tacit knowledge of consumers, market researchers and designers, by the development team to an explicit knowledge at a

Table 4.8 Knowledge conversion

Knowledge conversion	Place in product development	People, group
Tacit to tacit	Brainstorming, focus groups, discussion, concepts comparison	Consumer/designer Consumer/market researcher Designer/market researcher/process developer
Tacit to explicit	Product concept creation, product design specifications, modelling, feasibility reports, evaluation reports, production plan, market strategy	Consumer/designer Designer/process developer Development team/ functional depts/ management
Explicit to explicit	Business strategy/product development strategy, unit operations/new process, measures/testing techniques	Management/ product developers Engineers/ developers Quality assurance/ designer/developer
Explicit to tacit	Raw material specifications/ use in product, basic science/technology, reported experience/new problem, product problem/research for solution, product development project report/tacit model for organising future projects	Supplier/developer Researcher/developer Files/developer Consumer/ designer/developer Reports/product development manager

certain level. The design of the product and the process development then converts this often tacit description to a total product and process that can be described explicitly. Modelling is also a way of taking a tacit description of the product into an explicit description – the model can be verbal, physical, computer-based, or indeed mathematical. Explicit knowledge is exchanged in manuals, reports, papers, expert systems. Product design and production specifications, processing and quality assurance manuals, are commonly used for explicit knowledge transfers. It is important that the business, innovation and project development strategies, PD programmes and the aims and plans for individual projects are explicitly recorded for guidance of product development. Marketing can also be using point-of-sales data to develop their launch plan. The passing from stage to stage is often explicit going to explicit; for example the details of the product prototype going to the product specifications in production. It is important that this explicit knowledge is in a form that can be changed to tacit knowledge in a future project, projecting it with safety and confidence into a new area.

Organisational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge (Nonaka *et al*., 1996), and between individuals and groups and also the company as a whole as shown in Fig. 4.10. In product development, the product development strategy develops from the business strategy, gradually increasing the tacit knowledge to explicit knowledge, until individuals form from this an explicit product strategy. Note that even here is tacit knowledge, which has to be communicated to the product development team. Creating a product strategy involves a community of interacting individuals with different knowledge and skills. They have started with the explicit knowledge in the business strategy, and with group discussions are alternately increasing the tacit knowledge and building up explicit knowledge. In developing the new product strategy, there is a need to use not only the traditional analysis and experience, but also to have the strategic imagination to turn the input into new strategic scenarios (Ellis, 1999). There is a need to look in new directions, develop strategies that are innovative, unexpected, original and effective. At least once a year, board and key executives and selected product developers/designers need to

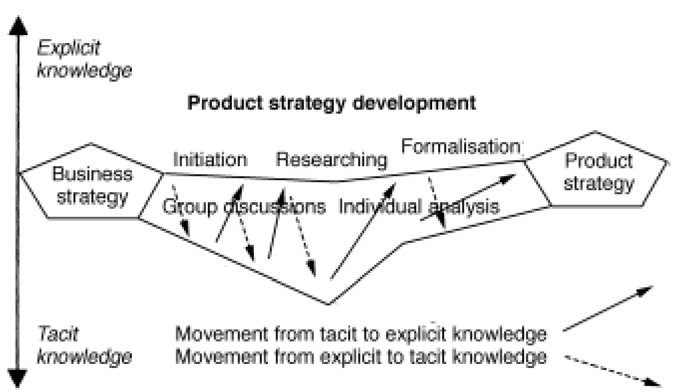


Fig. 4.10 Interaction of tacit and explicit knowledge in product strategy development.

meet to develop ideas for strategies in what Ellis calls serious play. Then management needs to build aggregate project plans, and create the development strategy. To make these activities work, the people charged with their completion need to be educated in the fundamental principles. They also need to enhance their knowledge regularly of the organisation's market position, technologies, production processes, suppliers and competitors (Clark and Wheelwright, 1993).

This process of knowledge building will be repeated in building up the product concept and the product design specifications. This time consumers will be included in the discussion groups with the product development team, marketing staff and technical staff. Product development teams move through these patterns of alternating periods of steady progress in knowledge creation, punctuated by sudden breakthroughs and sometimes changes in direction in the interacting periods. In creating knowledge, individual and group knowledge is interchanged, learning from each other, and then the combined knowledge for the problem is built. The combined knowledge then becomes the company knowledge in the future (Nonaka *et al.*, 1996).

Some of the important factors in using knowledge in innovation identified in the 3M company are shown in Box 4.3. All of these factors are related to knowledge, its communication and the empowerment of staff to use the knowledge. Perhaps the most important is the recognition that product development is a discipline with its own knowledge base. An important company capability in product development is having a thorough understanding of the market by acquiring, disseminating and using market information. But in many companies there are barriers to gaining market understanding, especially of new markets

Box 4.3 Important factors in innovation

- Vision for product development which is understood and accepted by management and the product development team, and is also related to the customer.
- Foresight which predicts the customers' articulated and unarticulated needs.
- Stretched goals, setting targets which cause the company to make a quantum leap.
- Empowerment, selecting the right people and then trust them enough to let them have the initiative to work on their own.
- Communications, the free exchange of information, staff understanding that combining and transferring knowledge is as important as the initial innovation.
- Recognition of the importance of innovation as a discipline in all parts of the company.

Source: After Ellis, 1999.

(Adams *et al.*, 1998). In acquiring market information, people focus on either technology design aspects (here is a new product, do you want it?) or business aspects (here is a product, what are predictions of sales revenues?). They ignore product concept development with consumers, identifying target markets and their needs and wants, because the researchers think these are ambiguous. Dissemination of market information is hindered because people focus on their own goals, often departmental instead of the project goals. Cross-functional approaches are needed to give interactive communication so that the market information is incorporated in the product design and also in the development of the marketing strategy. The learning barriers of compartmentalised thinking are overcome by:

- developing common goals that are specific to the product, not to separate departments;
- clarifying each person's role in the product innovation activity so that each knows their part in the larger whole and can help one another;
- learning to appreciate both the contributions from, and the constraints, in the various departments.

In knowledge use, the effort is to try to overcome the inertia to change. People tend to proceed as they always have, maintaining the status quo rather than adjusting actions to capitalise on market learning. Especially with incremental products, it is assumed that the product is just like the present products and there is no need for extensive market research; sometimes the research is done but ignored because it does not fit with preconceived ideas. Managers should enable teams to develop market data. Managers also must help people to extend the usual routines into new practices and promote trust between themselves and the team members, and also within the team. The product developers can make their product familiar to the manager by providing useful information about the product and its market. 'Useful' means that the managers could use the information to follow the development effort and evaluate the product's potential.

An important factor in the product development group is connectivity. People at one time worked in close-knit departments or teams where knowledge would be shared and exchanged routinely and easily. But today there is the problem of not only maintaining contact in a large building but maintaining contact internationally. The product development project team may have no physical contact and often work for different managers, and they may have never met – their only contact is by e-mail (Ellis, 1999). It has been shown that trust in team orientation, that is team members having reciprocal faith in others' intentions and behaviour to work towards team goals, rather than narrow, individual or functional goals or agendas, is essential. As well, trust in team members' competence is important – that they are competent to handle the complex and unknown problems that can occur (Madhaven and Grover, 1998). How does one trust someone through e-mail, far less work cooperatively with them when you have no idea of their knowledge, skills and personality? There needs to be recognition of the team and members do need to meet – not just for the one-day quick meeting but to work together on part of the problem, over several days and weeks. Team members who are able to interact face-to-face will be more effective and efficient at creating new knowledge. Management needs to understand that there are costs in running international product development teams if they are to be effective and efficient – both in having operational, interactive networks and also in having joint working times. Fostering an environment where people share information and knowledge because they know they will get appropriate credit for it, is an extremely important way to create intellectual capital within a company and keep it there.

The company needs to create an environment where individuals are encouraged to preserve and grow their own knowledge, and where they have the mechanism to develop personal relationships so that they share this knowledge with others in an informal interaction. They need to be encouraged to take risks together, and to actively seek knowledge to decrease the risks. The relationships should not be static but should be moving like a kaleidoscope to form new patterns of relationships and new groupings but with basically the same people. People will be lost from product development teams but, if they are properly run, not too often and not the ones who have high knowledge and/or the greatest ability in creating knowledge.

4.5.2 Managing creation of knowledge

In the management of product development Madhaven and Grover (1998) recommended the following:

- Selection of team members with specific knowledge and skills but also an appreciation of other areas of product development from education and experience, and with a shared vision of product development and its procedures. This can be difficult to recognise.
- Selection of the product development manager with multidisciplinary knowledge from education and experience.
- Using a product development process that is used in all similar projects, but could have variations for different levels of innovations and types of products. The decisions and outcomes for each project set out for each stage as well as the project overall.
- Ensuring that the members of the team are familiar with their intended activities, both through experienced team members and well-organised information sources.
- Education of team members on knowledge creation and storage. Also on how to share knowledge and create knowledge by team knowledge sharing and cross-functional development.

Development of people, values and culture in the product development team is very important. Investments in developing knowledge and skills, for technologies, marketing, consumer research and financial analysis, as well as the overall discipline of product development, can be made by employing suitable staff and by educating present staff. As Rouse (1992) said:

> Such investments make sense if the people involved have the aptitudes and abilities to gain the knowledge and skills, *and* if they will have opportunities to utilise the newly gained knowledge and skill. Without these prerequisites, well-intended investments in developing people can result in much frustration and not much else.

It is unfortunately fairly common in the food industry for this to happen, and a great deal of talent is lost because people are not allowed to use their knowledge but are tied to a bench doing routine work and not allowed any decision making. Product development is a risk-taking area and people must be allowed to engage together in setting the major decisions and outcomes, and then allowed to make the minor decisions themselves. Again they need to be involved in the discussion and choice of the major activities, and select their own activities and the techniques to be used in them. Techniques especially depend on the knowledge and skills of the people doing the work and if they do not have the major say in choosing the techniques within the constraints of the outcomes needed and the resource constraints, they will have less commitment. This is the way for people to develop their skills and problem-solving abilities. It means that managers have to take risks, because people may fail with poor outcomes or going over the time for the activity. But there are always failures and successes and managers have to increase their own knowledge to reduce chances of failure without reducing people to automatons. Although there are inevitably penalties for shortcomings and failures, it is very important that they be commensurate and not too severe. Managers need to recognise that they need by education to increase their professional knowledge regularly as well as their management skills. A manager needs knowledge across a number of technological areas to lead a product development team successfully.

There is also a need for everyone to recognise the culture and values in the team. If the values are human-centred both in the team and their development of products, then it matters little if a team is laid-back and casual, or conservatively dressed and formal. Different societal cultures outside the team, and indeed the company, affect this aspect of the team. Some cultures encourage communication at the personal level, others do not; and the problem is to give the team itself the values that encourage the sharing of knowledge and the working together. Values have to be realistic reflections of the general society, but they must also encourage effective and efficient product development. The company's values do come down from the Board and the top management, and it may in some cases be difficult to reconcile these with the values of product development. Apart from encouraging people to go to another company with values that are more consistent with product development, what can be done? Company values do change as was seen in the acceptance of total quality management – quality control was thought as only for technicians, until quality assurance and then quality management was developed and sold to management, mostly by outside public relations and sometimes even by government regulation. Product development has to be presented as a discipline and as a system that can produce dividends for the company, and all benefit if both management and the team see it this way.

Technical, organisational and commercial skills and knowledge required for improving product development are shown in Table 4.9. Three groups of abilities are essential for creating product development capability: technical, to achieve product and process integration; organisational, to create the capability of the team; and commercial, to develop effective product concepts and link customer requirements and unmet customer needs to the details of product planning and design (Clark and Wheelwright, 1993).

Some important knowledge seeking and knowledge communication areas in innovative companies (Souder, 1987) are as follows:

- Ability to sense threats and opportunities in a timely fashion, using environmental scanning, technological forecasting and competitive analysis.
- Study of risky opportunities, and accurate assessment of the degree of risk in a project.
- Well-developed project selection systems which effectively communicate the company's needs to the idea generators and foster decisiveness in goal-setting.

Table 4.9 Skill and knowledge requirements for improving development performance

Development participants	Skill/ knowledge requirements		
	Technical	Organisational	Commercial
Senior corporate managers	Understand key technical changes	Recognise importance of creating a rapid learning organisation, lead and provide vision and values	Identify strategic business opportunities
Business unit general managers	Understand depth and breadth of technology	Select and educate leaders, champion cross-functional teams, have career pathing for staff	Target key customer segments, architect product families and generations
Team leaders	Provide breadth of capabilities Comprehend depth requirements	Select, train and lead development team, recognise importance of attitudes and secure functional support	Champion concept definition, competitive positioning
Team members	Use new techniques, apply technologies, develop new technologies	Integrate cross-functional problem solving, create improved development procedures	Operationalise customer-driven concept development, refine concept based on market feedback

Source: Reprinted with permission of the Free Press, a Division of Simon and Schuster, Inc., from *Managing New Product and Process Development* by Kim B. Clark and Steven C. Wheelwright. Copyright © 1993 by Kim B. Clark and Steven C. Wheelwright.

- Interdepartmental debate focused on confronting and resolving conflicts to produce new ideas and a cooperative climate.
- Individuals who play reciprocal roles – persons who generate ideas, who champion these ideas and who link these ideas to the existing organisational goals.
- Organisational structures and climates that foster the development of collaborative roles.
- Long-term commitment to foster technology.

These qualities combined with a willingness of the company to accept change are fundamental to successful new product innovations.

Think break

Technological knowledge is organised and structured in ways that reflect application in product development. The product development team constructs its knowledge around the subsystems in the stages of the product development process. In this way its accumulated tacit and explicit knowledge is organised in the most effective manner for systematic product development and for the activities in each stage (Gawith, 1999).

1. Describe how your company has identified subsystems in your product development processes, and built up knowledge in these subsystems.
2. How do the product development team identify a problem, relate it to past problems and their solutions? Then decide on their method(s) for solving the present problem.
3. How does the team collect together its tacit and explicit knowledge to select the activities and techniques for solving the problem?
4. How does the company management ensure that the whole knowledge system is capable of producing efficient and effective product development?

Overall it is hard to overemphasise the central importance to product development of knowledge and its availability to the individuals and to the team who develop the new products. Some of this knowledge is explicitly written down and codified, but a great deal still lies with the particular people who do the creative work and collectively with their groups. From the viewpoint of the company's continued operation and success, and avoidance of risk from shifting employees, efforts are being made to maximise codification of knowledge. Modern information technology can do much to help with the machinery. Transfer to the record is also helped by the increasing understanding of the knowledge scene and of the philosophical issues on which it rests. But in the long run the knowledge, acquired skills, and powers of analysis and synthesis lying in the individual will always be the key resource. Without it, creativity will stumble, if not founder; with it, will come new products and commercial success relating strongly to the overall skill of the product developers.

4.6 References

ADAMS, M.E., DAY, G.S. & DOUGHERTY, D. (1998) Enhancing new product development performance: an organisational learning perspective. *J. Product Innovation Management*, 15, 403–422.

ALSTON, J.M., PARDEY, P.G. & WALLACE, T.L. (1997) Research policy challenges, in *Government and the Food Industry: Economic and Political Effects of Conflict and Co-operation*, Wallace, L.T. and Schroder, W.R. (Eds) (Boston: Kluwer Academic Publishers).

APFELL-MARGLIN, F. (1996) Introduction: rationality and the world, in *Decolonizing Knowledge: From Development to Dialogue*, Apfell-Marglin, F. and Marglin, S.A. (Eds) (Oxford: Clarendon Press).

BELCHER, J. (1999) Role of packaging in new product development. *IFT Product Development Newsletter*, 5.1, 4.

BETZ, F. (1998) *Managing Technological Innovation: Competitive Advantage from Change* (New York: John Wiley & Sons).

CAMPBELL, H.C. (1999) *Knowledge Creation in New Zealand Manufacturing.* M.Tech. Thesis, Massey University, Palmerston North, New Zealand.

CARDWELL, D. (1994) *The Fontana History of Technology* (London: Fontana Press).

CLARK, K.B. & WHEELWRIGHT, S.C. (1993) *Managing New Product and Process Development* (New York: The Free Press).

CLARKE, P. (1998) Implementing a knowledge strategy for your firm. *Research – Technology Management*, March–April 1998, 28–31.

COOPER, R.G. & KLEINSCHMIDT, E.J. (1988) Resource allocation in the new product process. *Industrial Marketing Management*, 17, 249–262.

COURT, A.W. (1997) The relationship between information and personal knowledge in new product development. *International Journal of Information Management*, 17(2), 123–138.

DRUCKER, P.F. (1985) *Innovation and Entrepreneurship: Principles and Practice* (London: Heinemann).

EARLE, M.D. & EARLE, R.L. (1997) Food industry research and development, in *Government and the Food Industry: Economic and Political Effects of Conflict and Co-operation*, Wallace, L.T. and Schroder, W.R. (Eds) (Boston: Kluwer Academic Publishers).

ELLIS, J. (1999) *Doing Business in the Knowledge Based Economy* (Amsterdam: Pearson Education/Addison Wesley Longman).

EVANGELISTA, R. (1999) *Knowledge and Investment: The Sources of Innovation in Industry* (Cheltenham: Edward Elgar Publishing).

FLECK, J. (1998) Expertise: knowledge, power and tradeability, in *Exploring Expertise: Issues and Perspectives*, Williams, R., Faulkner, W. and Fleck, J. (Eds) (London: Macmillan Press Ltd).

GAWITH, J. (1999) *Total Technology Practice: Preliminary Study for Application in New Zealand Schools*. M.Phil. Thesis, Massey University, Palmerston North, New Zealand.

GRAEF, J.L. (1998) Getting the most from R & D information services. *Industrial Research Technology Management*, July–August 1998, 44–47.

HOOD, L.H., LUNDY, R.J. & JOHNSON, D.C. (1995) New product development: North American ingredient supplier's role. *British Food Journal*, 97(3), 12–17.

LENZNER, R. & JOHNSON, S.S. (1997) Seeing things as they really are. *Forbes*, March 10, 122–128.

MACDONALD, S. & WILLIAM, C. (1993) Beyond the boundary: an information perspective on the role of the gatekeeper in the organisation. *Journal of Product Innovation Management*, 10, 417–427.

MADHAVEN, R. & GROVER, R. (1998) From embedded knowledge to embodied knowledge: new product development as knowledge management. *Journal of Marketing*, 62 (October), 1–12.

MARGLIN, S.A. (1996) Farmers, seedsmen and scientists: systems of agriculture and systems of knowledge, in *Decolonizing Knowledge: From Development to Dialogue*, Apfell-Marglin, F. & Marglin S.A. (Eds) (Oxford: Clarendon Press).

MARTINEZ, M.G. & BURNS, J. (1999) Sources of technological development in the Spanish food and drink industry. A 'supplier-dominated' industry? *Agribusiness*, 15(4), 431–448.

MITCHAM, C. (1994) *Thinking Through Technology* (Chicago: The University of Chicago Press).

NONAKA, I., TAKEUCHI, H. & UMEMOTO, K. (1996) A theory of organizational knowledge creation. *International Journal for Technology Management, Special Publication on Unlearning and Learning*, 11 (7/8), 833–845.

QUINN, J.B. (1992) *Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry* (New York: The Free Press).

ROUSE, W.B. (1992) *Strategies for Innovation: Creating Successful Products, Systems and Organisations* (New York: John Wiley).

ROWE, R. (2000) The right formula. *Chemistry & Industry*, No.14, 465–467.

SENKER, J. (1998) The contribution of tacit knowledge to innovation, in *Exploring Expertise: Issues and Perspectives*, Williams, R., Faulkner, W. and Fleck, J. (Eds) (London: Macmillan Press Ltd).

SOUDER, W.E. (1987) *Managing New Product Innovations* (Lexington, MA: Lexington Books).

TISSEN, R. (1999) Sharing knowledge does not mean giving away power: it offers a road to success, in *Doing Business in the Knowledge Based Economy*, Ellis, J. (Ed.) (Amsterdam: Addison Wesley Longman).

WALLACE, L.T. & SCHRODER, W.R. (1997) in *Government and the Food Industry: Economic and Political Effects of Conflict and Co-operation*, Wallace, L.T. and Schroder, W.R. (Eds) (Boston: Kluwer Academic Publishers), 107.