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Open Innovation: the New Way of Knowledge Transfer

Jan de Wit, Ben Dankbaar, and Geert Vissers

A Model of Knowledge Sharing in Biomedical Engineering: Challenges and Requirements

Aurilla A. Arntzen-Bechina and Carole A. D. Leguy

Value Pricing in the Chemical Industry - Most Powerful Lever to Profitability

Steffen Rüdiger, Clemens Elliger, and Christian Weigel

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Letter from the Editor

Struggling for profitability: not necessarily new, but challenging

In 2007 the chemical industry will face old and new challenges alike. Whereas the search for levers to increase profitability through cutting costs will continue, new regulations like REACH and a slowing growth of the whole sector are likely to increase the need for new solutions as well. In this issue an exciting mix of possibilities to meet these challenges is presented.

New markets and new products are getting more and more important as product life cycles get shorter and already interdisciplinary sciences converge further. Next to biotechnology, nanotechnology is a perfect example for such an interdisciplinary science. Virtually every day new discoveries are announced in nanotechnology, but the question remains: how to transform ideas into products? One important aspect is providing space and infrastructure and the organizational framework for the coming entrepreneurs. The CeNTech, one of the first such centres in Germany, is a very good example for such a successful incubator. In the commentary the concept of this creative institution is described.

The second article of this issue is focussing on Open Innovation as a new way for knowledge transfer. Although firms are realizing that they need to improve their innovation ability to foster growth and profitability, only few show a sufficient organizational capacity for generating "really new" innovations. This is especially the case in the chemical industry, which is developing fewer really new molecules that often only show incremental changes in properties, compared to existing materials. Against this background, it can be observed that more and more companies shift to an open innovation mode, but the pitfalls of this concept should not be neglected.

Even if the right, knowledgeable and innovative individuals are brought together in the right setting, the next challenge is just around the corner. How can people from completely different backgrounds share their knowledge and efficiently and effectively develop new products? This issue is being analyzed in the context of biomedical engineering in the third article.

Whilst most companies look at developing new products and reducing costs through cutting staff and increasing productivity only few look at one of the most powerful levers: the price for their products and services. In the light of this fact the Practitioner's Section is presenting a means for chemical companies to get what they deserve. Value Pricing means changing the perspective from the seller's side to the buyer's side – what is the value to my company for a product bought?

We would like to thank all authors and reviewers for their contribution to this selection of highly interesting themes. Now enjoy reading the first issue of the *Journal of Business Chemistry* in 2007. If you have any comments or suggestions, please send us an e-mail at contact@businesschemistry.org.

Clive-Steven Curran

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Commentary

CeNTech - Nanotechnological Research and Application

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Abstract: The Centre for Nanotechnology (CeNTech), Münster, Germany, represents one of the first dedicated nanotechnology centres in Germany providing space and infrastructure for application, research and development in the area of nanotechnology. It offers an optimised environment for entrepreneurs to further develop their research ideas into marketable products as well as excellent conditions for application oriented research and further education. Three years after the opening of the CeNTech building most of the expectations are fulfilled. The article describes the general aspects of the CeNTech concept and reviews its development in the first years.

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Introduction

Nanotechnology is a rapidly growing interdisciplinary field. To foster the cooperation between science and industry nanotechnology centres were founded. The centre for nanotechnology (CeNTech) in Münster was created as one of Germany's first centres of its kind being collaboratively supported by the state of North Rhine-Westphalia, the University and the City of Münster. CeNTech is located in a state exhibiting the largest number of inhabitants in Germany and is integrated into the densest network of universities all over Europe. Three years after CeNTech opening synergetic effects become clearly visible.

Concept and Ideas

The basic and overall concept of CeNTech provides the environment to perform basic research with strong application perspectives and to direct selected ideas and results of nanoscience into technical applications. Short in-house ways and a creative mixture between different scientific disciplines provide a fruitful background. Central to this basic concept is the promotion of start-up companies that originate from university research as well as the settlement of existing companies with nanotechnology and nanobiotechnology background. Evidently, patent support and contacts providing financial support are essential for the expansion of companies in the field. Another aim of CeNTech is the promotion of education ranging from level of schools to advanced training of external scientists in the field of nanotechnology, resulting in the concept of *Integrated Nanotechnology* (Figure 1).

CeNTech consists of a unique structure that has a complementing character in terms of combining research work and infrastructural, marketing, project proposal, exploitation, PR, patent, educational, and organizational activities. It consists of two different parts – a corporation (GmbH) and a research and development (R&D) department. Researchers and companies are supported by legal entity - CeNTech GmbH, i.e. a corporation providing an optimised infrastructure, support for preparation of patents, initiation and evaluation of projects, initiation and realization of know-how transfer towards industry, initiation and support of start-up founding processes, public relations, workshops, marketing and further education. By founding such an economically oriented structure research is transported much closer to the economic value creation chain. The gap between basic and applied research and industrial exploitation could be reduced significantly by implementing this system that actively seeks technological ideas, potential products, special know-how, and project ideas for third party funding. Researchers are interviewed in regular personal meetings where in a common approach the potential values shall be identified if not already clear. The researchers are well supported by the CeNTech GmbH and can therefore better focus on their main strengths and passion: research and development.

The R&D part of CeNTech is dealing with nanotechnology research preferentially in the areas of nanoanalytics and nanobiotechnology. Within these foci the projects in CeNTech include the optimization of scanning probe microscopy such as STM, AFM [1, 2] and advanced x-ray- and light microscopy techniques [3], the study of novel materials and nano-scaled template structures [4], the analysis of biophysical effects especially in intra- and intercellular processes, and the development of new approaches for the utilization of biological and biochemical processes in nanotechnology.

In these areas CeNTech researchers co-operate with groups in Germany, Europe and maintain close relations with research centres in the USA, Israel, China, and Japan, working together on nanoscience projects and exchanging visiting researchers. In particular CeNTech is engaged in the first German-Chinese Centre for Nanoscience (GCCN) which is based on a cooperation agreement between the State of North Rhine-Westphalia and the Chinese Academy of Science in the year 2000.

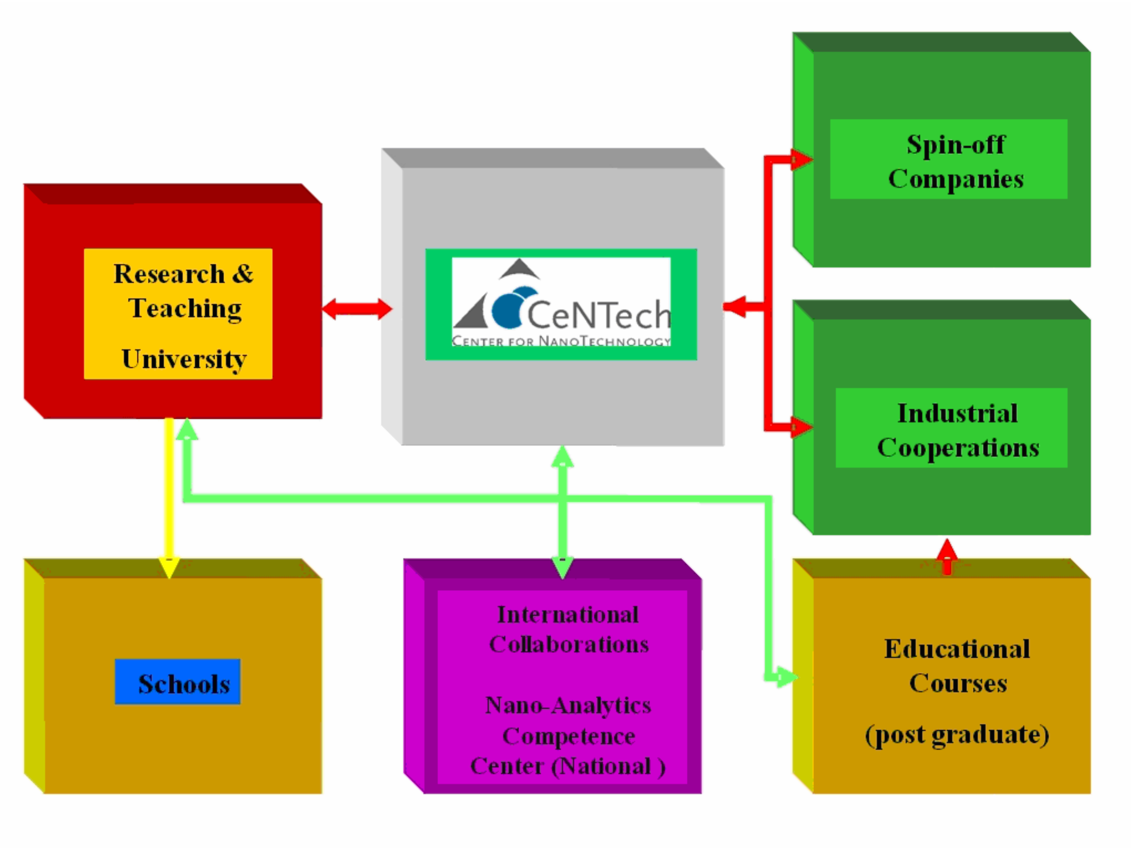

Figure 1: Integrated nanotechnology at CeNTech

The general research strategy follows a concept that formed the basis of a seminal scientific success in research laboratories of big US companies and which led to an unprecedented technological leadership over many decades. It consists, on the one hand of a fairly general topical framework or goal, which is sufficiently flexible to guarantee that new and completely unexpected technology leaps can occur, far beyond existing knowledge, linear product optimization strategies and the ostensible increase of market shares. On the other hand the general vision based on the product portfolio of the company had to be considered. Such a strategy has been leading, for example, to innovations such as the transistor, scanning probe microscopy, and high temperature superconductivity, to name a few. All these discoveries had a highly disruptive character making it virtually impossible to foresee their outcome just by evolutionary linear developments. The latter are extremely important and, in fact, indispensable in industrial product and method development including road map and milestone concepts etc., but seem much less efficient for the exploration of really new frontiers.

In CeNTech R&D, the participating groups originating from physics, chemistry, biology, biophysics and medicine are dedicated to application aspects of nanoscience and the fields of nano-(bio) analytics, nanomaterials and nanobiotechnology. One third of the total lab space of the CeNTech building is dedicated to nanotechnology-related companies, while the other two thirds of the building are operated by research groups from the university. The formal barriers for a membership are fairly high. It is first based on a scientific/technological proposal describing the research approach of the applicant followed by a description of the potential applications. In the case of a successful application the groups have to bring their own personnel and instruments. In addition they have to pay overhead fees for general research related duties of the lab. This means that the reach groups cannot participate, if they do not acquire external grants.

This concept resulted not only in over 100 high quality publications and more than 10 patent applications filed after three years but shows effects on the job market as well. More than 25 new positions were created within the last years and collaborating companies at CeNTech found new common customer markets that would otherwise have been inaccessible for the individual companies. Cooperation with SMEs and large companies from outside resulted in similar effects.

Nanotechnology at CeNTech

Nanotechnology is essentially based on physical and chemical effects that are characteristic for a certain small length scale, and which are not observed at larger length scales. As a consequence nanotechnology is rather an enabling technology than a specific technology field such as electronics, automotive or chemical industry. Thus, in contrast to existing technologies novel device and material properties arise, for example, by control of particle size (color, catalytic yield) tailoring electric transport properties, and applying of molecular recognition. This approach has a high potential to lead to disruptive progress in all technology fields, certainly with high risks but eventually substantially bigger economic opportunities as compared to conventional development strategies [5].

Based on the fact that

- physical techniques reach functional structures (mainly in electronics) down to the nanometer scale and microscopy and spectroscopy methods are reaching molecular and atomic resolution,
- chemists can prepare complex cluster- and supramolecular systems, and
- functional biological systems (membranes, proteins, molecular motors) are nano-sized,

it becomes self evident that the traditionally well-separated disciplines of physics, chemistry and biology naturally meet on the nanometer scale and can form a platform for novel scientific and technological strategies reaching far beyond the individual disciplines (Figure 2).

For example, in molecular biology, nanosys-

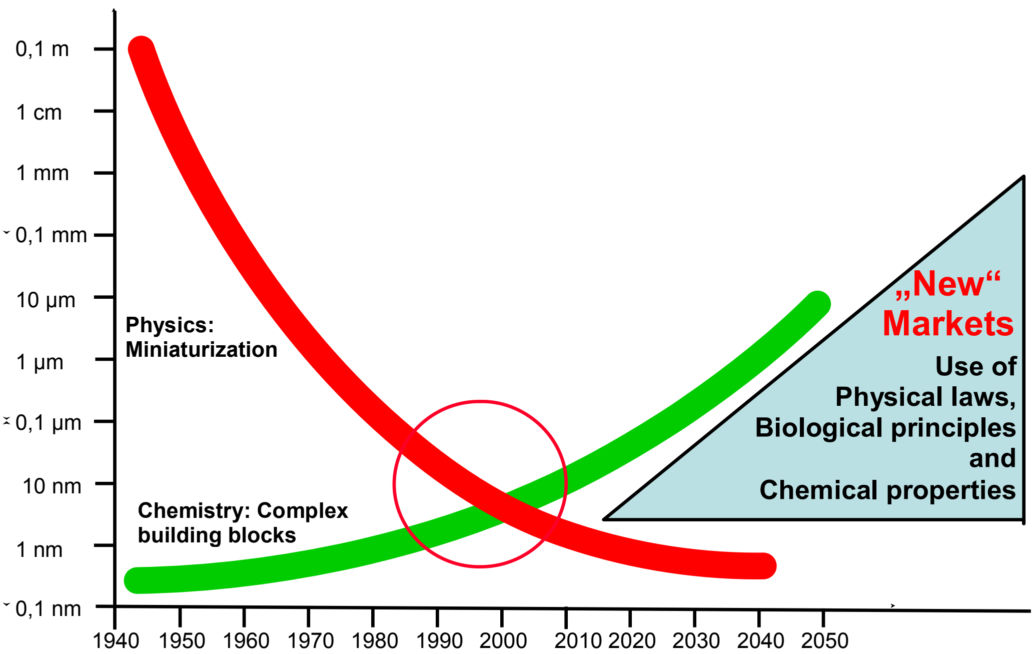

Figure 2: Nanotechnology - a transdisciplinary approach

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tems - like proteosomes and molecular motors - are the fundamental machines that drive the cell and they are components of mitochondria, chloroplasts, ribosomes, and the replication and transcription complexes. In catalysis, nanostructures are ideal reaction centres as are the pores of zeolites.

Each of the disciplines has evolved to some extend its own separate view of nanoscience. The opportunities for integrating these views and for sharing tools and techniques developed separately by each field belong to the most attractive activities ongoing in science today. Some of the challenges for research and development at CeNTech are presented below.

Surface Matters - a Glance at Scientific Work at CeNTech

The development of novel techniques for scanning probe microscopy is the prerequisite for an increasingly deeper insight into the nano world. This method is based on a revolutionary microscopy concept by Gerd Binnig and Heinrich Rohrer from the IBM research laboratory in Zurich, Switzerland, who, in 1981, built the first scanning tunnelling microscope. They were awarded the Nobel Prize in physics in 1986. Their method resulted in the development of a whole family of complementary techniques and made an extremely strong impact for getting nanotechnology really started.

Novel methods for improved visualisation of nano-scale structures and for even measuring the forces between individual atoms and molecules are developed at CeNTech. Questions such as the basic mechanics of friction and wear can be addressed on the atomic scale (Figures 3 and 4) [6]. It becomes particular evident in this field that the boarders between basic research and application become fuzzy.

Another topic of CeNTech research is the preparation of self-organised molecular layers. Usually, molecules or atoms – i.e. the building blocks of all materials – are arranged in a more or less randomised fashion in existing products. Using self-organization techniques ubiquitous in biology molecular building blocks arrange themselves spontaneously and in a well defined position. They may eventually lead to novel and useful macroscopic systems based on cooperative effects which then are technologically relevant as, for example, nanostructured templates and scaffolds [7].

Materials produced in this way exhibit totally new electronic and optical properties and, in the extreme case, are only as thick as an atomic or molecular monolayer. This technique is highly demanded for a whole range of applications. In future it will be possible to build electronic chips with huge memory capacities, to house a whole bioanaytical laboratory on the size of a thumbnail, or to build organic light emitting diodes with tailored optical properties. According to the interdisciplinary character, the investigation of interaction between nanoparticles and nanostructured surfaces is another new research topic. Here the action of

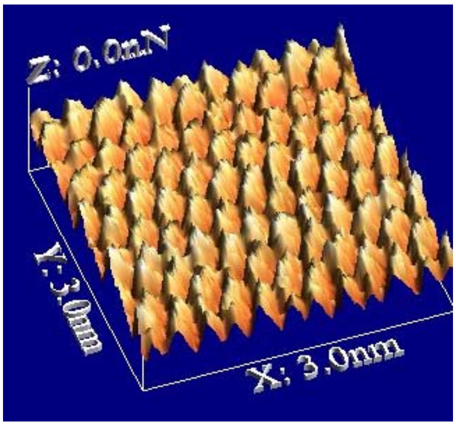

Figure 3: "Lateral Force Microscopy" on single carbon atoms on a graphite surface

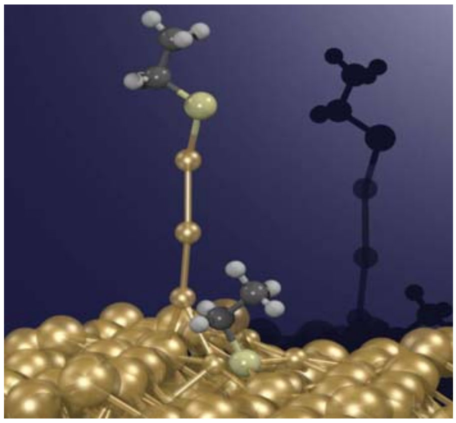

Figure 4: Molecular tweezers – Mechano - Chemistry

those structures on the immune system will be investigated to make a risk assessment and to find new applications for medical devices.

The research fields performed in CeNTech include

- Design of novel scanning-probe techniques [8, 9] and advanced optical and x-ray methods.
- Manufacturing and characterisation of supermolecular, self-organizing film-systems (Langmuir-Blodgett, self-assembly-techniques) [4, 7])
- Molecular Beam Epitaxy (MBE) for the construction of novel electronic systems based on organic molecules [4]
- Development of theoretical models related to scanning-probe techniques

Beyond Electron Micoscopy (SEM), Photoelectron spectroscopy (XPS) and other surface analytical techniques a state of the art dual beam Focussed Ion Beam (FIB) system is available at CeNTech. Important applications are nanoscale machining, the modification of the electrical routings on semiconductor devices, the preparation of probes for physico-chemical analysis, or the preparation of ultra precise sections for transmission electron microscopy (TEM), just to mention a few examples. In what dimension manipulation is possible is demonstrated in Figure 5.

Figure 5: CeNTech logo written on a hair with a Focused Ion Beam (FIB) system,

In addition to the above mentioned research areas CeNTech offers several groups of young scientist the great opportunity to develop their own research fields in nanotechnology.

Biological Barriers - Cooperation and Development at CeNTech

Indicative for the interdisciplinary character of nanoscience at CeNTech is the cooperation between the groups. Within the framework of a special research area of the University of Münster, scientists work together on the deliberate modification of cellular membranes. Biological membranes are made of water-repellent, fat-like molecules with built-in protein molecules serving as transport slices. The whole exchange of matter within and between cells is being arranged and controlled by these slices. Biochemists work on the modification of definite bonds within the fatty acids of the membrane in order to make them less water-repellent, thus gaining novel surface-active properties. To achieve these aims, biochemists use the nanotechnological brick box of the partners [10, 11]. The final application area of this research cooperation is in medicine. The development of implants which take root particularly well in the body without causing unwanted immunological repulsions is only one possible end product of this nano project in Münster.

The presence of the biochemists at CeNTech was not only fruitful for scientific reasons. In cooperation with *nanoAnalytics* - a company located in CeNTech - a new product was made ready for market: the so-called cellZscope® (Figure 6). With this new device the impedance, i.e. resistance and capacitance of biological barriers can be characterised as a measure for the correct contact between the cells of a cellular monolayer [12]. It is a tool that can be used e.g. as a substitute for animal testings to investigate drugs and the biocompatibility of nanoparticles.

These are a few examples which demonstrate the interaction between science and SMEs. Other companies and researchers like e.g. a group dealing with the optimization of nanostructures for protein and DNA synthesis are as well successful at CeNTech.

CeNTech fosters not only the interaction between science and industry but also that of SMEs

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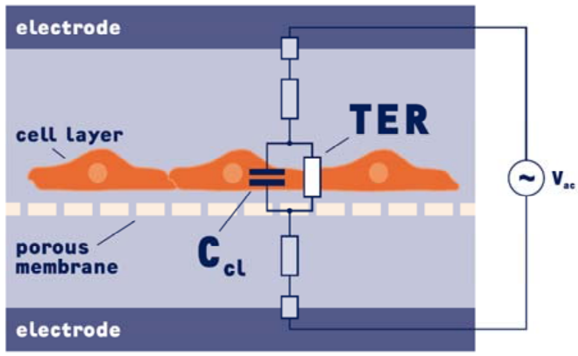

Figure 6: cellZscope® - photography and basic principle of the device

and big companies which leads to new additional market shares on both sides.

Another example for a company hosted by CeNTech is *arrows biomedical Deutschland GmbH*. It is an independent, international medical and scientific consultation and service firm, which advises and supports business, research institutions and hospitals in the area of molecular biomedical sciences. An intensive cooperation with NIKON Mikroskop GmbH enables them to work with advanced high-quality optical microscopes. All employees within the company are physicians and scientists, who continuously work on innovative methods of problem solving in molecular biology and medical science. Close collaboration with all disciplines open contacts and applications within nanoscience as well as in stem cell research. The expanding company appreciates the transdisciplinary environment as well as other companies like *Chembiotech*, *Tascon* or *nanoAnalytics* hosted by CeNTech.

Conclusion

After its first three years of operation CeNTech has formed a new regional platform in the field of nano(bio)technology which combined basic research and technology transfer in an efficient way. Researcher groups at CeNTech have acquired more than 12 Mio € during that time on a national and European basis beyond their individual funding in their mother institutions of the University of Münster. Clearly, some of the big instruments such as advanced laser scanning microscopy, UHV- (ultra high vacuum-) surface inspection tools and the Focused Ion Beam system can be used much more efficiently at CeNTech than by an individual group in one of the discipline-separated scientific faculties. The mixing of optimised laboratories, common seminars and meeting rooms etc. generated a new creative atmosphere resulting in much new interdisciplinary collaboration including the in-house companies. CeNTech as a unit also provides strong support for companies and press presentation, education, and workshops. Several young researcher groups were established which are of particular interest for the initiation of new interdisciplinary educational and research approaches. One of the secrets of CeNTech's success is the freedom that established groups, and in particular young researchers have in performing their research. This freedom is due to the financial concept that is based on the individual external funding of peer reviewed projects that are harboured in CeNTech, rather than institutional contracts provided by the unit. The dynamics and freedom resulting from this concept as well as interdisciplinary science and development creates a great potential for innovation. The job generating effect of CeNTech is the strongest index for the quality of the strategy of this centre.

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Research Paper

Open Innovation: the New Way of Knowledge Transfer?

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Abstract: Due to globalization, competition has increased and companies have reorganized their activities in order to maintain profitability. The consequence has been an emphasis on short term results, at the expense of long term research. Therefore, most Corporate Research laboratories were closed or built down considerably. However, long term research is required for products that are difficult to copy by competitors. Moreover, companies have come to realize that only radical innovation, based on long term research, will distinguish them from their competitors. Since the end of the 1990s, attempts are being made to combine short term financial interests with long term innovation requirements. Many of these attempts can be classified under the heading of Open Innovation, which may be viewed as a company's endeavour to profit from external knowledge without making heavy internal investment in long term research. This paper examines the prospects of Open Innovation, on the basis of own research and reported literature work. It is argued that companies cannot totally rely on external sources of knowledge, and that new ways must be found to compensate for the results that used to be achieved by companies' own Corporate Research.

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Introduction

As a result of the massive use of internet and the very cheap world-wide transport costs in the early nineties industrial competition has increased dramatically [1, 2]. This has resulted in price erosion and consequently in margin erosion of most products sold by industry. Most companies have addressed this problem by cutting the costs for long-term activities like research towards radical innovation. The result has been that although the financial performance of most companies could be maintained, at the end of the nineties companies have realized that working on the short term has resulted in incremental innovations that can easily be copied by competition [3].

Due to the abovementioned observations industrial research currently has a time horizon of maximal three years [3] and over the years few companies have been able to maintain the know-how for radical innovations that require 10-15 years between the idea generation and the successful application on the market.

However, in order to maintain a competitive position on the long term radical innovation is necessary [4-6]. But how can industry become involved in this process if they do not seem to have the know-how anymore?

This subject has been discussed by many authors [see e.g. 7-13].

One of the possibilities is that industry makes more use of the scientific results produced by universities. Although there is a massive literature on cooperation between knowledge institutes and companies we believe that we can classify all these activities in five categories:

- Through a (university) Technology Transfer Office (TTO)
- Direct cont(r)act between industry and university
- Contact between university and industry through an intermediate
- Funded by government (direct and indirect)
- Through spin-off companies

The different classes of transfer of knowledge between university and industry, directly or indirectly, can be visualized in Table 1, where also the appropriate literature references are given.

Class	Sub class	Literature references
TTO		14, 15
Direct contact		6, 16-23
Intermediate	Research Joint Venture	24, 25
	External partnership	26-28
	Public Private Cooperation	29, 30
Government supported	Direct	31-33
	Indirect	19, 34, 35
Spin-off companies		34, 36, 37

Table 1: Classes of knowledge transfer between university and industry

From all the literature covered no single mechanism surfaced whereby industry could innovate in a radical way based on science created by university. A recent study by our group [13] showed that although a carefully chosen intermediate for example a Leading Technological Institute [38, 39] already contains most of the conditions that are noted in the abovementioned literature to achieve such a transfer successfully, the recipient side (the industrial researchers) lacks the scientific quality to be able to absorb the LTI results (see also under Discussion).

New mechanisms therefore have been proposed in the literature to address the problem of assisting companies to innovate more radically of which the most recent one is "Open

Innovation" [40]. Since this new form of innovation is very recent, not many articles [see for instance 41-44] have already been published on this topic. In this respect it can be added that in our current research new ways will be investigated (for instance by letting a post-doc work in the company to get the results embedded in the company or by starting a spin-off company first; both are forms of Open Innovation) to shorten the distance between the abovementioned LTI results and companies.

This article intends to investigate whether companies that are focused on the short-term are able to use the "Open Innovation" method as a new way of knowledge transfer.

We use hereby – in analogy with the definition of Innovation – "any form of cooperation with third parties that can contribute to improve the long-term performance of a company".

First R&D projects from 21 companies in three sectors have been classified in four categories and then in each category the intensity of cooperation with third parties was established.

Methods

In September 2004 the authors of this article have started the Micord Group at the University of Nijmegen, The Netherlands. Micord stands for **M**anaging **I**nnovation, **C**ooperation and **O**utsourcing in **R**esearch and **D**evelopment. The program content is based on an observation that is also valid for "Open Innovation": a growing number of companies is using different external sources in their innovation process. To manage innovation in collaboration with external sources presents new and difficult problems to companies. It also raises issues of innovation- and technology policy for governments.

The issues to be investigated have been grouped into three levels:

Collaboration Types of collaboration, choices to be made, partners in the innovation chain, conditions for success, bottlenecks, role of intermediary institutes

Organization Role of corporate functions, absorptive capacity, links between research categories, differences between large and medium sized companies, influence of social and economic priorities

Sector Patterns per sector, links to science and technology, differences within and between sectors, influence of public infrastructure

In the first year patterns of collaboration and outsourcing have been studied in three important sectors of industry in the Netherlands: Food, Equipment Manufacturing and Polymers. We have used an Interview Guide comprising 27 questions to interview leading R&D officers from 21 different companies, five in Food, nine in Polymers, and seven in Equipment Manufacturing. It has to be remarked that the companies selected were in their sector in the Netherlands the leading companies as far as R&D spending is concerned.

The major conclusions from this research will be reported elsewhere [45] and can be summarized as follows:

The sectoral perspective is useful. It emphasizes the enormous variety of influences present in different contexts – in terms of competitive forces, consumer preferences, government regulation, and technological change. Related to this, the number and character of relevant actors in each sector is also very different. It is not always easy, though, to identify proper boundaries for a sector and it turns out to be even more difficult to collect reliable information on a sectoral basis. Also due to industry convergence in formerly separated industries (e.g. Nutraceuticals) sector boundaries are more difficult to make. The taxonomy of sectors developed by Pavitt many years ago [46], turned out to be helpful for the organization and interpretation of the sectoral findings. According to his taxonomy Polymers fall in the category Science Based, Food in the category Scale Intensive and Equipment Manufacturers in the category Specialized Equipment Suppliers.

The flow of knowledge between universities, non-profit research institutes and companies is less intensive, less structured and more dependent on incidental and personal contacts than might have been expected. In spite of the existence of the Leading Technological Institutes and in spite of the existence of a specialized

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research university in the field of food and agriculture, cooperation between university institutes and companies appears limited. Generally, the fact that there is only limited cooperation appears to be a result of a considerable gap between the kind of knowledge universities are generating and the knowledge companies might find useful. This gap is seldom blamed on university professors losing themselves in useless, overspecialized exercises, but rather more frequently on the considerable time and investment needed before the knowledge generated by the universities can be put to commercial use. Companies, including their R&D departments, are unwilling and / or unable to get involved in projects with a long-term perspective, even if they potentially could lead to radical innovation. This raises various questions concerning the interaction between corporate innovation strategies, the 'absorptive capacity' of companies, the programming and control of academic research, and the transfer and 'valorization' of such research. The case of consumer electronics also raises questions about the impact of vertical disintegration and geographical dispersion of elements of the value chain on knowledge sharing and the innovative capacities of companies.

The realization of radical innovations is very difficult in modern corporations organized in business units operating with a very short time perspective. Research is driven by the same short term perspective and where this is not the case, researchers find it difficult to get business units interested in product ideas that go beyond the current portfolio. Companies are increasingly aware of this problem and are exploring various solutions involving the creation of new units or companies by means of venture capital funds, incubators and other arrangements. There is a clear need for research departments to have access to marketing knowledge. Entrepreneurial capacities are also in short supply.

Out of the available results from this study [45] we have selected the part that is in our opinion extremely useful to understand the potential of "Open Innovation".

This part deals with the classification of research projects in the following four categories (see also Figure 1):

Category A: mainly supporting research activities for the **current** product portfolio; these activities have a short-term focus

Category B: adaptation of **existing technologies** for **new markets**; for instance making polymers for paints suitable for printing inks

Category C: development of **new technologies** for the **existing markets**; for instance developing waterborne polymers for paints where now solvent-borne polymers are used

Category D: development of **new technologies** in **new markets**; for instance waterborne polymers for printing inks where now solvent-born products are used

In this respect "new" (both in technology and market) means new to the company (expansion of the geography is not considered as a new market).

We have asked all companies as part of the interview to answer the following questions:

Can you indicate in Figure 1 (see below) the number of FTEs (full time equivalents) working on R&D projects in each quadrant in your R&D organization and also per quadrant the number of FTEs involved in cooperation with third parties?

Although not all companies were familiar with the model presented, they all were able to supply the figures from their R&D budgets.

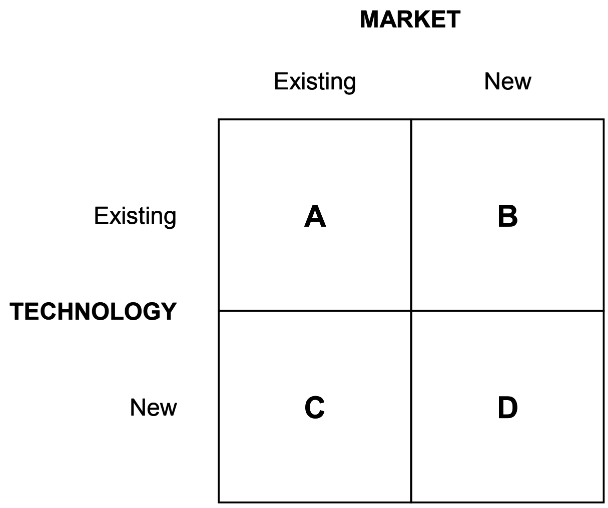

Figure 1: Division of R&D projects over 4 categories

Results

For all 4 categories results per sector have been obtained. A total of 2,430 FTEs (1005 in Food, 1,252 in Polymers and 173 in Equipment Manufacturers) have been assigned to projects from the companies we have interviewed. Out of this total close to 20% are involved in cooperation with third parties in general.

The results per sector have been summarized in Table 2, where for each quadrant the column **R&D** means the number of R&D FTEs per sector and the column **COOP** the number of R&D FTEs involved in cooperation with third parties in that sector.

The results in this table can also be presented in a relative way (Figure 2).

Quadrant	**A**		**B**		**C**		**D**	
	R&D	**COOP**	**R&D**	**COOP**	**R&D**	**COOP**	**R&D**	**COOP**
Food	502	0	232	72	196	53	75	53
Polymers	535	14	204	27	332	73	182	73
Equip Man	23	0	2	0	78	60	70	57

Table 2: Number of FTEs involved in cooperation per sector in each quadrant

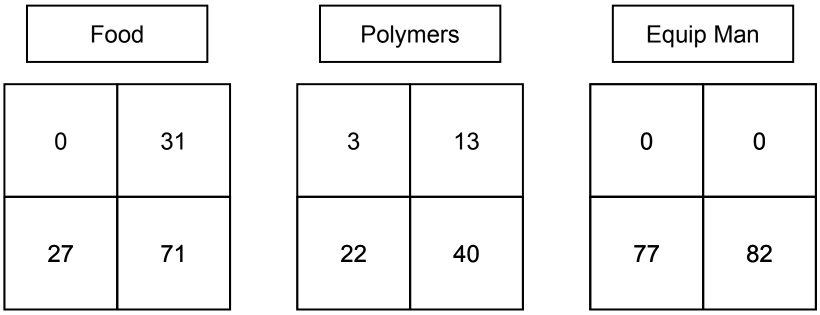

Figure 2: Percentages of cooperation in different sectors

In each quadrant per sector the percentage of cooperation is given.

Table 2 and Figure 2 suggest very clear differences between sectors concerning the distribution of R&D efforts over the quadrants, and concerning the proportion of R&D collaboration involved:

- Most R&D efforts focus on existing markets (total of quadrants A and C is much more than 50% of the total)
- R&D collaboration is virtually absent in R&D work that concerns existing technology/existing markets (quadrant A)
- To some extent in the food sector (and to a small extent in the polymers sector) R&D collaboration is present in R&D work that concerns existing technology/new markets (quadrant B)
- In the machinery and equipment manufacturing sector (and to a lesser extent in the other sectors) R&D collaboration is present in R&D work that concerns new technology/existing markets (quadrant C)
- In all sectors R&D collaboration is present in R&D work that concerns new technology/new markets (quadrant D), but more in the machinery and equipment manufacturing and in the food sector than in the polymers sector.
- The percentage of R&D collaboration in the machinery and equipment manufacturing sector is considerably higher than in the other sectors.

A more general observation is that the percentage of FTEs involved in cooperation with third parties is highest in the quadrants C and D, which is to be expected since companies are usually not willing to share their existing technologies with others.

More interesting is then the question with whom the companies cooperate.

The summary of the findings is given per category.

Category A: hardly any cooperation at all; cooperation with other companies (competitors!) undesired

Category B: cooperation takes place with other companies, especially those that are already active in the new markets to be explored; universities are only used to understand the technology (e.g. analysis)

Category C: almost all projects in this quadrant are a cooperation with universities to develop the new technology, as here the cooperation with other companies active in the same market is undesirable

Category D: very often new projects are initiated in collaboration with specialized institutes like the Dutch Polymer Institute for the sector Polymers, the Wageningen Center for Food

Science for the sector Food and the Institute for Metal research for the sector Equipment Manufacturers. Very often this is pre-competitive research where companies develop the new concepts together with scientists

If the definition of "Open Innovation" is "any form of cooperation with 3rd parties that can contribute to improve the long-term performance of a company" then the picture above demonstrates that this new paradigm is not yet fully embraced by companies. Taking into account that we only have interviewed R&D intensive companies, the fraction of FTEs involved in cooperation with external sources is a disappointing 20%. All interviewed companies only indicate cooperation with Universities in quadrant C and that means with the data from Table 2 that max 186 FTEs are involved (about 7.5%) in cooperation with universities.

Discussion

From the limited set of data presented and the limited information from the open literature we can conclude that companies are not yet massively embracing the new paradigm of "Open Innovation". And maybe that is for a good reason. During the time that Corporate Research flourished in multinational companies (1965-1995) there was intimate contact between these research institutes and universities [see for example 47]. When however due to the effect of globalization (massive use of internet and very cheap transportation costs) competition increased, companies started reducing costs to maintain margins and profits. Because the explicit results of most Corporate Research Laboratories were not very visible in the bottom-line of the companies' profit and loss statements, most companies have decided to build down their corporate research. In the current situation, where research is carried out close to the customer, interaction with universities is much more difficult than in the past because the business researchers do not speak the academic language anymore.

Although the explicit results of Corporate Research was in most cases hard to find there were a number of intangible reasons (assets of a Corporate Research organization that are very difficult to measure) that were underestimated by the top management of most companies. The values associated to these intangible reasons were:

- newly hired employees could work for a certain period in Corporate research after which a career path could be established

- many business researchers used Corporate research as a sparring partner for difficult research questions

- Corporate researchers were able to judge the quality and applicability of academic research

- Corporate Research was seen by the universities as an equal and therefore serious partner

- in times of less business questions the researchers could be temporarily placed in Corporate Research

It is very questionable whether the new wave of "Open Innovation" can replace the abovementioned values. Although for instance the Shell Company has announced very recently that they will restart their Corporate Research it will not have the size the former KSLA laboratory had. It is not unlikely that other companies like Rohm and Haas and DSM will follow with a form of Corporate Research.

We can therefore safely conclude that although "Open Innovation" seems a promising way to improve the long-term performance of a company without having to invest heavily in their own Corporate Research organization, much more research is needed to find out how to realize this improved performance.

This will be the focus of the research of the Micord group in the coming years, whereby both the subject "improve the ability of companies to innovate more radically" as well as the subject "better use by companies of the science developed at universities" will be investigated in the three mentioned sectors Polymers, Food and Equipment Manufacturers.

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Research Paper

A Model of Knowledge Sharing in Biomedical Engineering: Challenges and Requirements

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Abstract: Technology has always played an important role in medical science by contributing extraordinary advancements to health care. Archaeological excavation shows that the Greek society had already used tools to explore the human body in order to understand human physiology and to diagnose normal and pathologic states. In the last four decades, emerging biomedical engineering sciences have led to the manufacturing of cutting edge medical instruments. Those technical tools are used to enhance clinician's know-how by providing better knowledge of the human anatomy. A more accurate diagnostic is crucial for medical practitioners in order to suggest an appropriate treatment. For example, the introduction of endoscopes into surgical practice is considered as one of the biggest success stories in the history of medicine.

However, in order to develop suitable medical instruments or procedures, one key issue for successful biomedical research is the ability to understand the requirements as defined by medical doctors. Furthermore, biomedical universities and the biomedical industry, who are the two main actors of the development process of new technologies, need to collaborate and cooperate in an efficient way with medical staff. This ongoing study intends to explore the nature and the role of knowledge transfer between the various stakeholders with the aim to develop innovative medical instruments. Factors inhibiting or facilitating knowledge sharing processes are outlined in this paper.

Introduction

It is well recognised that during the last decade our society has turned to be knowledge oriented (Corso, Martini, Pellegrini, Massa, & Testa, 2006) and that the need to cope with knowledge and its management is one of the main concerns of innovative organizations. Previous studies indicate that there is a link between knowledge management and innovation processes (Arntzen 2006; Brännback, Renko, & Carsrud, 2003; Cormican & O'Sullivan, 2000).

Lately, the emerging concept of a triple helix, representing the way how three institutional spheres (public, private and academic) work together is considered as being the best approach to form an innovation system based on knowledge flow and interactive consultations (Leydesdorff & Meyer, 2000). For example, the European consortium, ArtMed, aims to develop a new portable and real time ultrasound scanning device able to detect early vascular diseases. The partners involved represent three different groups such as universities (Eindhoven University of Technology), hospitals (European Hospital Gorges Pompidou), and manufacturers (Esaote S.p.A). They constitute a typical example of the triple helix concept (Esaote, 2005) in the field of biomedical engineering.

Biomedical engineering (BME) is defined as the application of engineering disciplines and technology to the medical field. It combines engineering expertise with the medical expertise of the physician to help improve patient health care by designing suitable medical devices. As a relatively new discipline, much of the work in biomedical engineering consists of research and development. Therefore, it is crucial that health institutions, research institutes and manufacturers work efficiently together.

One way to ensure success in these types of cross-disciplinary activities is to examine the way scientific knowledge flows between engineers, researchers and physicians while they are involved in an effort to develop or improve diagnostic devices. In this paper, we focus especially on knowledge transfer and sharing processes.

Transfer or sharing of knowledge is no longer considered as a linear process from a source to destination, but it is seen as a spiral pattern of linkages between the three institutional bodies (Leydesdorff, 2003).

Usually universities in the triple helix represent the core partner having the potential to carry out research activities conducting industrial innovation (Grossman, Reid, & Morgan, 2001). However, knowledge and technology transfer from universities to industry is often not optimal. It is acknowledged that it is not unusual to miss opportunities to improve or develop innovative products; this is mainly due to the lack of close and efficient collaboration and cooperation (Brännback, Renko, & Carsrud, 2003; Pérez & Sánchez, 2003).

In addition, researchers at universities who work in an isolated context are often not aware of the needs and challenges of potential target user groups. Thus, some important research efforts can lead either to no concrete outcomes or to results that cannot be exploited or commercialized (Sandelin, 2003).

This statement is even more valid in the biomedical engineering field, where there is a stringent need to ensure close cooperation between University-Hospital-Industry while developing specific tools and procedures to be used by clinicians. The cooperation and collaboration between the three stakeholders involve an effective knowledge transfer and sharing process. Therefore, it is important to determine the factors and channels allowing knowledge and technology transfer to occur (Laestadius, 2004; Leydesdorff & Meyer, 2000; van Baalen, Bloemhof-Ruwaard, & van Heck, 2005).

Obviously, it is important to initially define the nature and topology of the knowledge that is transferred and to be shared before identifying the appropriate channels.

Our research study intends on one hand to explore the nature and the role of knowledge transfer between the various stakeholders and on the other hand to determine the socio-technical factors enhancing knowledge management leading to technology innovation in the biomedical engineering field (Bechina, 2002).

In this paper, we intend to answer the following research question:

- What roles do the use of information communication tools and organizational change play in transferring and sharing knowledge fostering innovative activities in the biomedical engineering field?

The next section introduces the concepts of knowledge and knowledge transfer. Part three describes the context of the study and outlines the challenges and requirements of knowledge transfer within the biomedical engineering field. Finally a model of knowledge transfer and sharing is discussed.

Knowledge and Knowledge Management Concepts

It is usually agreed that no standard definition of knowledge exists. One of the most referenced definitions in the literature is provided by Davenport and Prusak (1998): "Knowledge is a fluid mix of framed experience, values, contextual information, expert insight and grounded intuition that provides an environment and framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of the knower. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" (T. Davenport & L. Prusak, 1998).

Knowledge is defined as information in a context that is embedded in action (Brooking, 1999). It is also seen as a shared collection of principles, facts, skills, and rules (Pemberton & Stonehouse, 1999). In this respect, knowledge is what gives "meaning", thus the lack of significance leads to disorganized information (Bhatt, 2000). In addition, knowledge is seen as very subjective, because it depends on the beliefs, values, intuition and emotions of the individual (Sunassee & Sewry, 2002).

Furthermore, it is necessary to recognize the different types of knowledge in order to expose its potential contribution to the performance of the organization and to determine the appropriate channels to transfer it (Pemberton & Stonehouse, 2000). Wide-based knowledge definitions highlight the presence of several forms of knowledge; tacit, explicit, implicit and systemic knowledge on the individual, group and organizational levels (T. H. Davenport & L. Prusak, 1998; Dixon, 2002; Inkpen, 1996; Nonaka & Takeuchi, 1995; Polanyi, 1958).

Explicit knowledge has a tangible dimension that can be easily captured, codified and communicated. Explicit knowledge is referred as "know-what". It can be shared through discussions or by writing it down and stored into repositories, documents, notes and so forth. Instances of explicit knowledge might include a network directory, an instruction manual, or a report of research findings. In contrast, tacit knowledge is linked to personal perspectives, intuition, emotions, beliefs, know-how, experiences and values. It is intangible and not easy to articulate and tends to be shared between people through personal interactions. Tacit

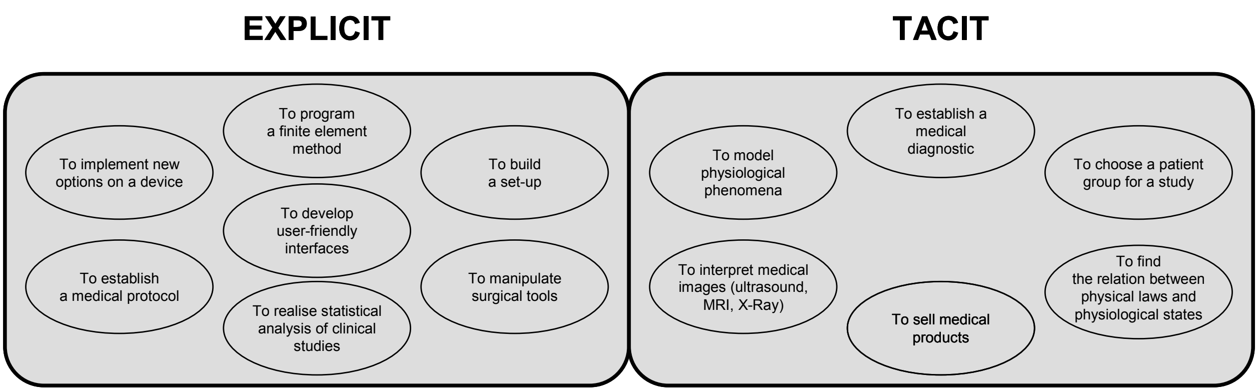

Figure 1: Example of tacit and explicit knowledge in the context of the biomedical field (source: own figure)

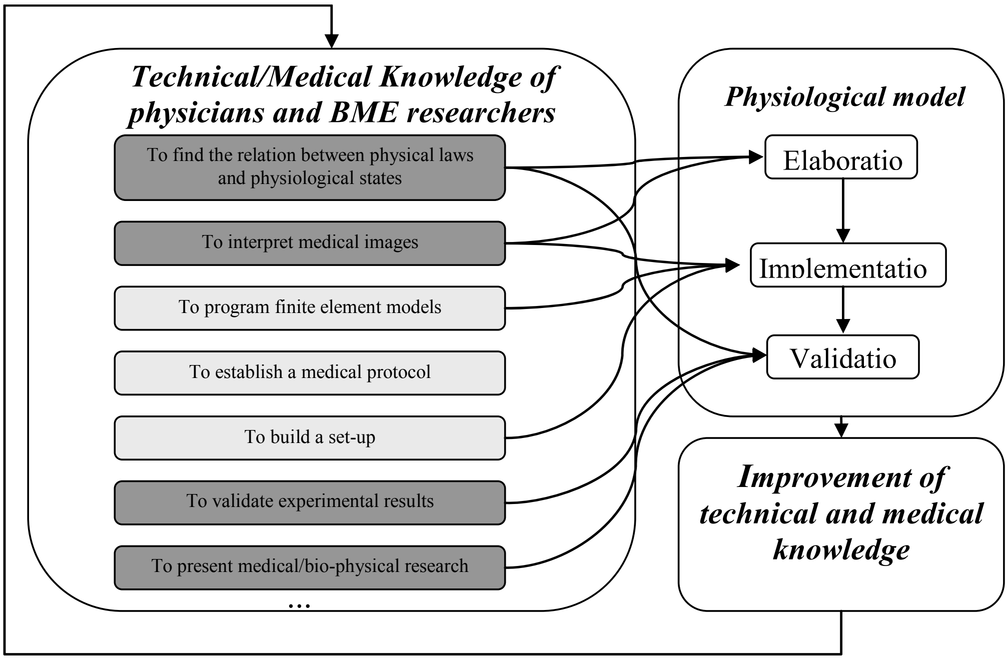

Figure 2: Example of the knowledge requirements during a physiological model development process; tacit and explicit knowledge are differentiated by dark and light grey backgrounds respectively. (source: own figure)

knowledge is both social and contextual, therefore it is a complex task to store and communicate it (T. Davenport & L. Prusak, 1998).

Figure 1 provides examples of tacit and explicit knowledge in the field of biomedical engineering.

For instance, an accurate interpretation of a medical image such as MRI (Magnetic Resonance Imaging) requires tacit knowledge of the physician. This type of knowledge comes from their experience of interpreting and will depend on the contextual setting. Physicians can establish a diagnosis by following a medical protocol that is described usually as a set of rules.

The distinction between tacit and explicit knowledge is important since their management is quite distinctive and requires different channels or means to transfer or to share it.

However, quite often the use of tacit or explicit knowledge is entangled, and it is often hard to have a clear separation between them.

Figure 2 outlines an example of tacit or explicit knowledge needed for the delineation of a physiological model.

In addition, Nonaka & Takuchi (1995) propose a model of knowledge transfer or a creation process (SECI). Figure 3 illustrates four modes of knowledge conversion between tacit knowledge and explicit knowledge. Knowledge conversion starts with the tacit acquisition of knowledge by people who do not have it from people who do. This process is called socialization.

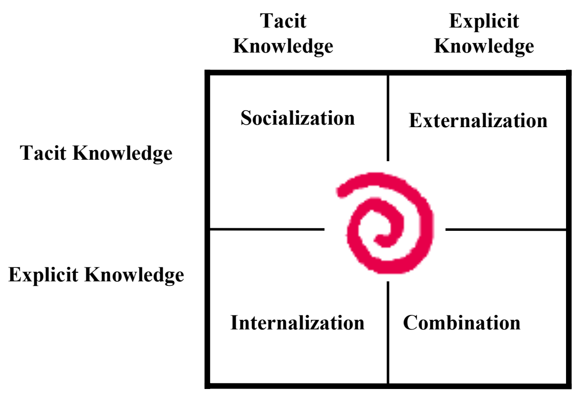

Figure 3: The SECI model of knowledge creation and transfer process (source: Nonaka & Takuchi (1995))

- **Socialization:** from tacit to tacit -- It is defined as sharing experiences to create tacit knowledge, such as shared mental models and technical skills. This also includes observation, and practice. It also builds a shared context in which learning and assimilation processes are facilitated.
- **Internalization:** from explicit to tacit -- Explicit knowledge is embodied into tacit knowledge. This is referred to as "learning by doing." Knowledge is articulated or diagrammed into documents or oral stories.
- **Externalization:** from tacit to explicit -- The process of articulating tacit knowledge into explicit concepts uses metaphors, analogies, concepts, hypothesis, or models.
- **Combination:** from explicit to explicit -- The process of systemizing concepts into a knowledge system triggered by networking.

Knowledge management (KM) is seen as an effort to increase useful knowledge within the organization by encouraging communication, offering opportunities to learn, and promoting the sharing and transfer of appropriate knowledge artifacts (McIrnerney, 2002).

"Knowledge management caters to the critical issues of organizational adaptation, survival and competence in face of increasingly discontinuous environmental change. Essentially, it embodies organizational processes that seek to synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings" (Malhotra, 2003).

The high number of different definitions of knowledge management highlights the diversity of the knowledge management processes ranging from knowledge codification, representation, transfer, sharing, classification, search, generation, use and so forth.

In our research study, we focus mainly on the knowledge transfer and sharing process. It is important to understand how the transfer of knowledge from one set of individuals to another is taking place. Alavi and Leidner (2001) emphasize the significance of knowledge transfer by discussing the need for an organization to be successful in its ability to generate new knowledge and to transfer it (Brennenraedts, Bekkers, & Verspagen, 2006).

In the context of high-tech biomedical engineering, we need to comprehend the mechanisms and channels for transferring knowledge in order to enable innovation. A model of knowledge sharing and transfer is discussed in the following section.

A Model of Knowledge Transfer and Sharing in Biomedical Engineering

A Challenges and Requirements

In the context of fast technological changes, successful organisations need to be innovative. The biomedical engineering field deals with cutting edge technology and represents major stakes for society and government. Recent studies demonstrate that medical innovations play a crucial role in improving health and life expectancy. For instance, increases in the life expectancy resulting from a better treatment of cardiovascular disease from 1970 to 1990 have been estimated to bring benefits worth more than $500 billion a year for the United States (Tyler, 2006).

Thus, research and development activities are crucial in the design of innovative medical instruments and will contribute to an improvement of the health care system by enabling a better diagnostic and treatment.

One key issue for successful biomedical research is to ensure an efficient collaboration between the three main actors involved in the development of medical instruments. Figure 4 illustrates the interaction between health care institutions, biomedical engineering (BME) industry and university.

Both biomedical universities and biomedical industries (the two main actors of the production process of new medical tools) should be able to collaborate with medical specialists. Obviously, the main characteristic of a biomedical project is the multidisciplinary context. This, in turn, emphasizes the need to foster a knowledge flow (sharing and

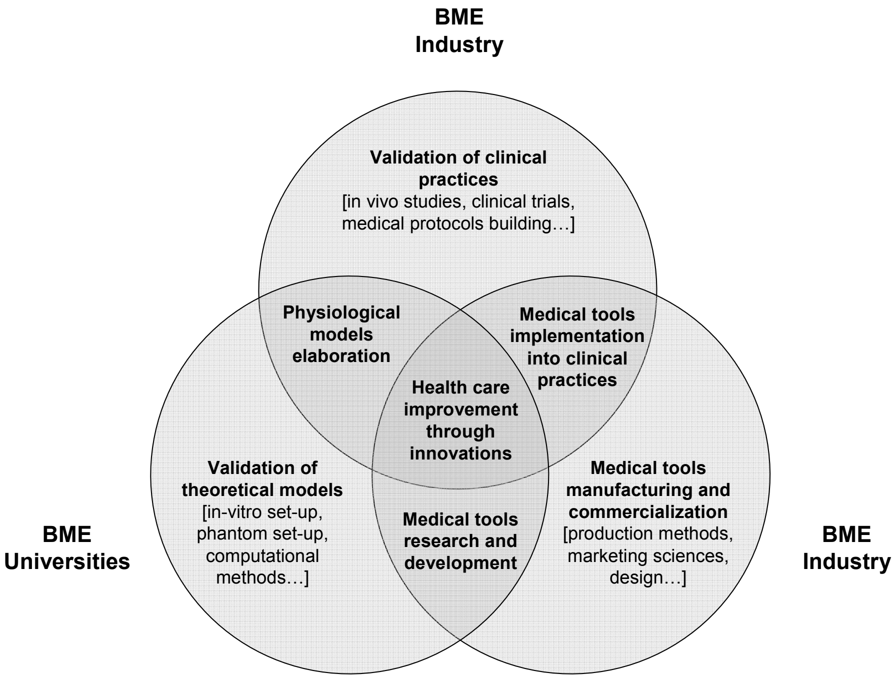

Figure 4: Triple Helix: Three clusters involved in Biomedical engineering effort (source: own figure)

transfer) at various levels through stronger and controlled interactions.

These main challenges rely not only on understanding why knowledge sharing and transfer processes are crucial between the different biomedical partners but also on understanding how knowledge sharing is occurring.

BME industry and medical institutions need to collaborate closely while implementing medical instruments into clinical practice. For instance, physicians can observe the physiologic and pathologic states of patients while using medical instruments. Building knowledge is a process that needs to be recorded in order to provide crucial feedback data to companies. This typical phase of knowledge sharing/transfer is important in improving the functionality of medical instruments.

Examples of other collaborative activities involving knowledge flow between medical institutions and BME companies include:

- Requirement of engineering specification
- Validation of new devices by clinical trials
- Training of staff in the usage of medical tools
- Maintenance, quality, and configuration management
- Security, ethical issues, medical legislation
- Quality/price balance

Elaboration of a physiological model requires a strong cooperation between BME universities and medical institutions. The research activities involve both technical and medical knowledge (see Figure 2). For instance, typical knowledge flows will result in the specification of physiological models reflecting the link between medical observations and physical theory. These cross-fertilization activities involve the commitment and understanding from both communities.

The benefits gained from the cooperation between universities and industries are well known. For example, companies are usually profit-driven and the harsh competition might influence their research strategy focus and internal resource allocations. Therefore, one way to acquire crucial knowledge that can build their competence in developing innovative medical instruments is to establish research collaborations with research institutions.

Finally the intersection in the triple helix illustrates that collaborations and an efficient knowledge flow contributes to health care system enhancement. However, observations indicate that although the need to cooperate is well assessed there are still some challenges to overcome and some requirements to fulfil.

For instance, it is vital that technical engineers are able to properly understand the medical context. Usually the first phase in the medical instrument design involves requirements of engineering. This step is the most important since the requirements expressed by medical practitioners should be well understood and analysed in order for the engineers to specify correctly the functionality of the instrument. Therefore, engineers and medical specialists should adopt a common vocabulary that will facilitate communication.

In practice, lack of technical or medical knowledge is the source of misunderstanding or bad interpretations and can induce costly errors while designing a tool.

Traditionally, technical researchers (engineers) were still too little attracted by clinical applications. This was partially due to the low job market offer. However, during the last few years, the increased demand for improved medical devices and systems is said to contribute to the rapid rise in biomedical engineering jobs. Another factor preventing engineers from choosing to specialise in medical tools design is the belief that the strong socio-medical culture will impact negatively on their working process.

On the other side, observations show that health professionals do not use technological systems effectively in their daily routines. In fact, general research studies confirmed that there is rather a latent or open hostility to fully exploit the functionality of information systems or high-tech medical instruments (McDermott & O'Dell, 2001). Furthermore, despite the fact that several ”breakthroughs” in scientific and technological knowledge have been validated through clinical trials, many medical tools are still not adopted by practitioners (Hilton et al, 2002). The reasons usually invoked were related to the instrumental complexity, lack of appropriate training, instruments not really adapted to all patients, high costs, lack of awareness of the potential of some medical instruments, and different medical approaches or protocols adopted by physicians (Le Houx, 2002). These can lead to strong challenges and prevent an effective exploitation of technical knowledge in medical practices.

In addition, end-users complain that medical devices persistently present malfunctions. However, recent studies indicate that the problems were caused rather by medical device usage errors. Indeed, there is widespread evidence that a large number of device usage errors are the result of poorly designed user interfaces (Le Houx, 2002; Todd R. Johnson et al.).

Finally from the business point of view, it is noticeable that academic researchers do not address marketing or commercialization issues and therefore collaborating with industry will ensure that innovative ideas will not be lost. Of course, companies will deal with patent and confidentiality issues and therefore knowledge sharing will not take place spontaneously.

Therefore, collaboration between the three types of organisations is as well characterised by the need to provide a viable business model for the industry. The final purpose for the manufacturer is the production of new medical tools at a larger scale. Of course those business considerations should also be integrated in the set of requirements leading to the technical specification of the medical tools. Other requirements such as ethical issues (compliance) and knowledge of medical legislation have to be considered as well. Collaboration and knowledge flow processes should be clearly outlined for the three partners and some examples of benefits are outlined as follows:

- Quality improvement in development of appropriate medical tools due to feedback from the users (clinicians)
- Development of medical tools that suit the needs of user groups better
- Universities will benefit by testing their concepts and by applying their fundamental research
- Industry will benefit from the expertise of top specialist researchers and can expect to improve their own expertise as well as

extend their portfolio with new competences acquired while collaboratively designing new medical tools

B Knowledge transfer and sharing model

This research project is still ongoing, but we are already able to draw a general knowledge sharing/transfer model. The delineation of the model is based on:

- Literature reviews
- Informal meetings and discussions with managers, engineers, researchers and physicians
- Punctual observations of work practices and knowledge transfer processes
- Document analysis

The model as illustrated (Figure 5) indicates that knowledge transfer and sharing processes can take several forms and occur at different levels in the pyramid.

At the bottom level of the pyramid, the people-based layer is the most important and should be the pillar for the knowledge sharing process in a biomedical engineering project. In order to overcome the differences of the three communities, it is crucial to define a framework where technical and medical knowledge can flow without meeting resistance from people. The top level of the pyramid indicates that although technology can be very useful to transfer or share explicit knowledge, the implementation and use of technology should be the last knowledge management focus.

People: Knowledge management is first and foremost an effort to manage, develop, and disseminate knowledge and the full potential of people at an individual, team-based, and organization-wide level. Providing the right cultural environment is the most challenging effort but achievable by enhancing learning facilities, providing a trustful working atmosphere, where collaboration and sharing are encouraged. Other aspects that need to be considered include: motivating and rewarding people that create, share and use knowledge, encouraging communities of practice and promoting network creations.

Processes: Processes play an important role in providing support for any KM implementation. Organisations might need to restructure their internal processes or even the organisation structure itself in order to support KM processes such as knowledge sharing or transfer. Managers must identify knowledge that exists in various forms in the organisation. One way to achieve the goal would be, for example, creating a knowledge map by initially finding out where knowledge resides, point it out and then provide instructions on how to get there.

Technology: Providing a knowledge portal, linking people by e-mail or building knowledge repositories contributes efficiently to sharing

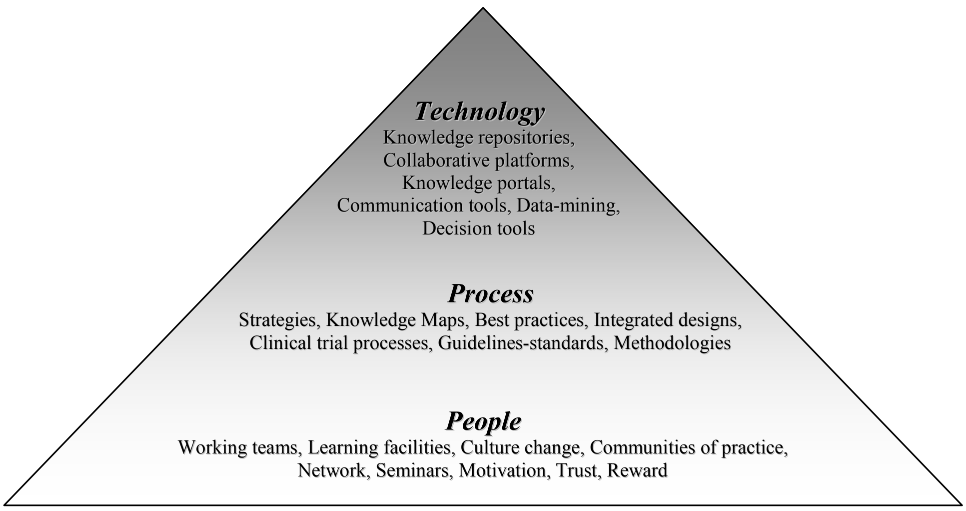

Figure 5: Knowledge sharing and transfer model (source: own figure)

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knowledge. However, using technology alone will not ensure successful knowledge management as organisational factors such as adequate training needs to be taken into account as well.

Focusing mainly on using technology to support knowledge sharing or transfer, building knowledge repositories might actually slow down the process of sharing. This is mainly due to the fact that many clinicians are reluctant to use information communication tools on a daily basis. Therefore in this specific context, it is important to prioritise the human side by encouraging training of biomedical engineers and clinicians under co-responsibility of educational teams composed of both medical and technical specialists. Such early stage collaborations should foster better communication by exposing involved stakeholders to different cultures. Focus on other processes such as for example, best practices dissemination, needs also to be considered (Bechina , Michon, & Nakata, 2005).

Before implementing some parts of the model, it is crucial to understand and consider the factors that will inhibit the knowledge sharing and transfer. One of our previous studies has resulted in the definition of a generic framework encompassing factors facilitating and inhibiting the knowledge sharing (Arntzen-Bechina 2006; Arntzen-Bechina & Worasinchai, 2006). The next step of the current project is to map early findings within the biomedical engineering field.

However, an analysis of preliminary data collected via informal meetings/discussions and observations outline other factors preventing knowledge flow within hospital or university. They are briefly described below.

Ą *Diverse areas of expertise:* Although researchers in the biomedical field are supposed to have double competencies and to interface between technical and medical areas, it is still challenging to exchange knowledge. This is partially due to the absorptive capacity of the receiver. Preliminary interviews showed that physicians were not especially interested to know all the technical aspects of a medical device while researchers were not necessarily keen to have an in-depth medical knowledge. This, in turn, increases the problem of communication when they are working together on either user requirements elicitation or on the validation of a medical device. Obviously, the difference in expertise slows down the knowledge sharing/transfer process and is a source of misunderstanding.

Ą *Problems with sharing beliefs and cultural norms:* Cultural norms differ and represent in fact a major obstacle in knowledge sharing. For example, the dominant cultural factor in a medical system emphasises the individual responsibility of physicians. This creates a climate of non-transparent communication where errors made are not exposed and discussed. It might happen that the border of errors due to either malfunction or bad manipulation is not well clearly defined. Therefore, improvement of a medical device can be hampered. Socio-medical culture deals as well with ethical issues such as specific data of patients that should not be available for a third party. Physician's value resides in the principle of helping patients and not business corporation, independently of the cost. Therefore, it is recognised that it is impossible to impose business principles or systems thinking on physicians (Richard, 2003).

Another example is related to the clash between academic and business culture. Universities do not emphasise the need for profit or companies cultivate the sense of ownership and patents.

Ą *Internal conflicts and difference in interests:* Each institution has its own objectives and its internal interest does not necessarily match the objective of a biomedical engineering project. For example, some research institutions aim to advance the fundamental research while health professionals intend to provide the best care for a larger number of patients. Thus, health professional might not be too keen to engage in clinical trials with unpredictable outcomes for the patient's health. In addition, the companies' focus is to become a profitable organisation. Therefore, they might have to scale down functionality of medical instruments if the reduction of costs has an impact in terms of selling.

Ą *Lack of incentives and rewards for sharing tacit knowledge or using Information Communication Technologies for sharing explicit knowledge*

Ą *Motivational issues and lack of time:* Even if the value of using a medical instrument is well understood by physicians, it is not obvious that they are willing to spend a lot of time on defining users' requirements or providing systematic feedbacks. The workload in hospitals is considered to be quite heavy and most physicians argue that helping patients is their first priority.

Ą *Rigid and or highly hierarchical organizations:* Hospitals are usually large and very complex organisations and generate an environment where communication and changes take time and energy. For example, decision making is not a fluid process and it is not unusual that even if it is recognised that collaboration is needed, still there are some barriers to overcome due to many reasons such as regulation on freely accessing data or clinical knowledge.

Conclusion

The paper discussed the need to understand the knowledge sharing process in the biomedical engineering field.

We presented the preliminary results of a research project that aims to analyse the knowledge flow between the three main institutions involved in a biomedical engineering project. The initial data collection is based on literature reviews, observations and informal interviews with key persons from each organisation. This first step has led to the identification of three elements impacting the knowledge sharing process, i.e. people, process, and technology. Some factors facilitating or inhibiting the transfer of knowledge have been outlined and discussed.

We can conclude that a systematic approach is required and should encompass the following steps:
Firstly, it is important to identify the key knowledge workers within the organizations and launch a campaign of communication stressing the importance of sharing knowledge. Some incentives or rewards need to be established in order to motivate all the knowledge workers involved in the process of developing new tools or technology. The third phase should be dedicated to the design of specific sharing mechanisms facilitating the knowledge transfer. One indispensable issue is related to set up some metrics to measure the impacts of knowledge transfer during the design of innovative medical instruments. It is clear, that the choice of metrics relies heavily on the type of initiatives implemented for transferring knowledge. The focus might be either organizational change or the use of appropriate information communication tools.

This study is at an earlier phase, and we intend at a later stage to collect quantitative data from different stakeholders in order to understand the current knowledge transfer that is in place and to provide a set of recommendations in order to improve the flow of knowledge in the triple helix university-hospital-industry

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Practitioner's Section

Value Pricing in the Chemical Industry – Most Powerful Lever to Profitability

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Abstract: The chemical industry in Europe is working hard on the improvement of their profitability base. But while innovation and complexity management are heavily discussed by the industry's top managers, the most powerful lever to increase profitability is being ignored by many – value pricing. Arthur D. Little, jointly with Warwick Business School, conducted a pricing survey with the participation of managers from all chemical industry segments in which measures for profitability increases were investigated. Although a price increase of 1 % can lever the profit (EBIT) by 8 %, many companies focus on much weaker levers like reducing variable costs and sales volumes. In this article we look into the possible benefits of value pricing, the effective BASF approach and the problems posed by a customer management focussing on the perceived strategic importance of customers rather than their contribution margins.

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Introduction

The chemical industry in Europe is facing various economic problems: long life-cycles result in margin decays, Asian competitors bring heavy price-pressure into the market and costs saving measures seem to be exhausted. However, various methods and possibilities still do exist in order to increase company's profitability – the most important being value pricing (Figure 1). The central idea of value pricing is to measure the customers perceived value (i.e. "his willingness to pay up to X") and to set the price accordingly. However investigation on this topic proofed that most companies in the chemical industry have no or limited professional pricing methods since pricing seems to be perceived as not manageable. This is an amazing finding, as value pricing is the most powerful lever for profitability increases.

Arthur D. Little, jointly with Warwick Business School, conducted a pricing survey with the participation of managers from all chemical industry segments in which measures for profitability increases were investigated.

The results show that managers believe innovation to be important for market success with the latest and promising trend being value based pricing. The majority of interviewees indicate that in the future customer specific contribution margins will play a more significant role. Among other interesting insights of the survey is the finding that it is not sufficient to introduce professional price finding methods in the company. The key success factor is the commitment and alignment of the top-management that will translate into sales force's pricing rules. Overall intuitive negotiating should be avoided and a systematic and structured approach be introduced.

Innovation and pricing are the topics most discussed in the chemical industry today. Survey results give evidence for the positive sensitivity effect of professional pricing. Price increases of 1 % lever the profit (EBIT) by 8 %. Variable costs and sales volumes - being considered key performance indicators by top management - have a lesser effect: changes of 1 % lever profit (EBIT) by 4 % on average.

Bearing this in mind, it is particularly interesting that for roughly half of the interviewees pricing is not considered a top management issue, although optimised pricing could offer attractive opportunities.

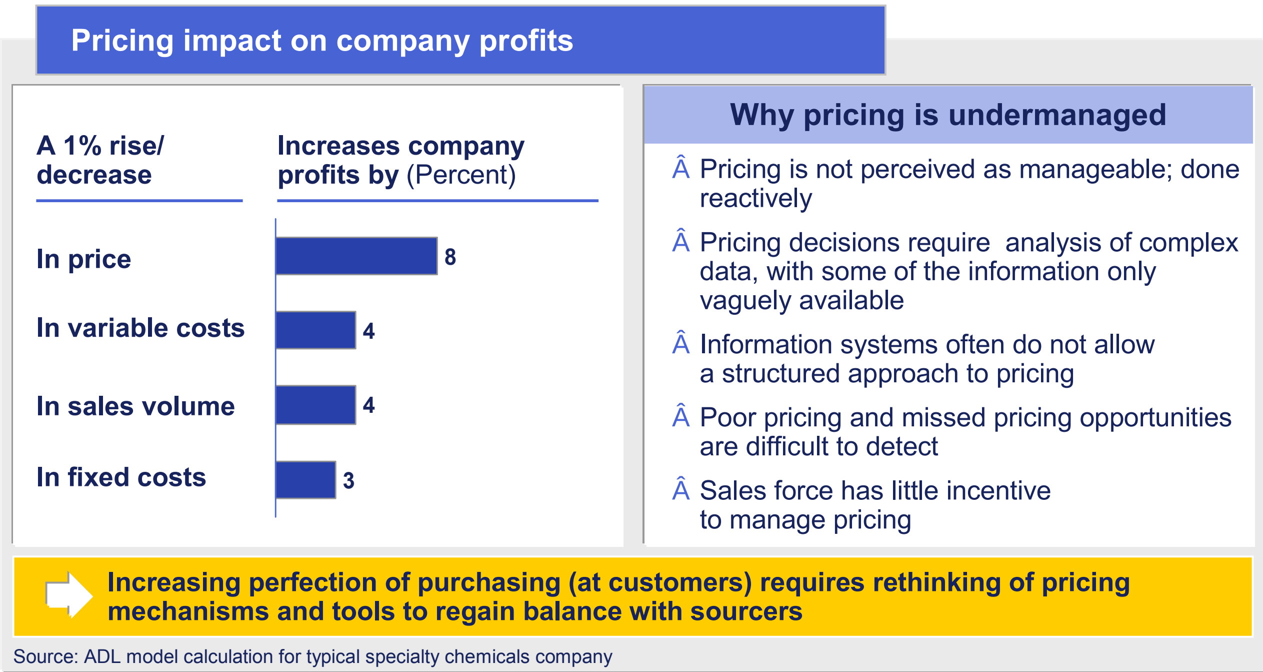

Figure 1

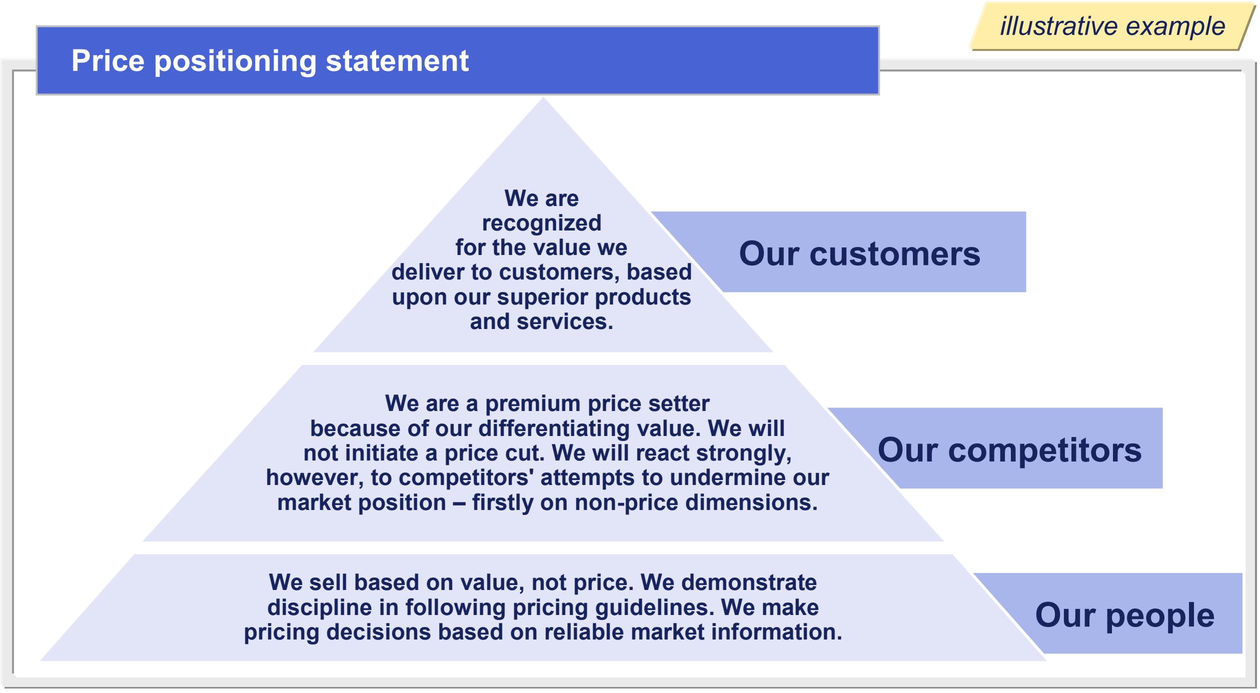

Figure 2

On the other hand some top players have already reacted. The chemical company BASF has implemented value based pricing in the recent 2 years, now benefiting from these measures (see Appendix 2).

Charging for the Perceived Value

There is no clear picture for the pricing situation in the chemical industry: additional services such as consignment warehouses or 24-hour delivery service are often offered – but not charged. The survey confirmed that many companies have difficulties in quantifying the maximum value of a product perceived by their customers. On average, a price is determined by comparing to the relevant competitors' prices as a reference. This can only work if the competitor accommodates professional pricing methods. Otherwise competition will suffer from orientation towards the supposed price leader. Furthermore this method distracts from an unbiased view at the strengths and advantages of the company's own products – and this in turn means that pricing differentiators are not being charged for!

However, value based pricing should not be confused with just higher prices. It is important to understand that value based pricing charges proper prices - not just higher ones.

The Sales Force Needs a Different Incentive System

Most sales representatives in the chemical industry obtain salaries according to their sales numbers but mostly not to customer contribution margins. The survey shows that 75 % of the participating companies have an incentive system which measures sales force achievement according to their sales. Only 21 % consider the contribution margin of individual customers. This is a remarkable yet typical practice. Whereas high sales targets often justify and promote excessive price discounts, lower price limits beware ("walk-away-price") from unprofitable decisions. But this assumes main focus at customer contribution margins. This result seems to be recognized by the participants of the survey: value pricing methods will be considered as most relevant in the sales and marketing segment (from 34 % today to 68 % in the future) followed by complexity management (from 23 % today to 55 % in the future) and price controlling (from 19 % today to 54 % in the future).

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Three Steps on the Way: Strategic Pricing, Operational Pricing and Implementation

The question remains how companies of the chemical industry should set up pricing initiatives to achieve pricing excellence. For a successful roll-out top managers must be aligned on strategic and value pricing initiatives as well as committed to their implementation. First of all the difference between the strategic and operational project phases must be drawn. Whereas during the strategic phase it is important to ensure the buy-in of top-management and to define roles and responsibilities, the operational phase is more about implementing and imposing initiative measures in the market and in the enterprise.

The key question is which tools the sales department needs to implement and hold the newly calculated prices in the market. In any case at the initiative's end simple and binding guidelines need to be set up for the sales force. Going operational can only work if the sales force team knows the rules and support it. Arthur D. Little developed an easy-to-use electronic tool (dashboard) that helps sales forces identify and put a price on customer value. Before programming the dashboard, a so called "price positioning statement" has to be developed. Necessary for the statement is to find out what customers want and what the maximum price for which service will be. This is similar to provoking the additional services the customer is willing to pay for. From our experience one can say that many enterprises offer services which cannot be charged. These should be eliminated from the portfolio.

Behind this complex model is a simple approach: loyal customers should be rewarded for their buying behaviour and be kept. In some cases companies should refrain from keeping unprofitable customers.

A Sensible Task - Key success factors

A price increase of 1 % not only leads to a profit increase (EBIT) by 8 % - but unfortunately this works vice versa, too. It proofed to be extremely important for a pricing excellence project to provide the right tools to the sales forces. These tools calculate the price level at which a product can be offered – below this level selling is unprofitable and should not be done. Successful pricing methods work with many dimensions: exact knowledge of customers,

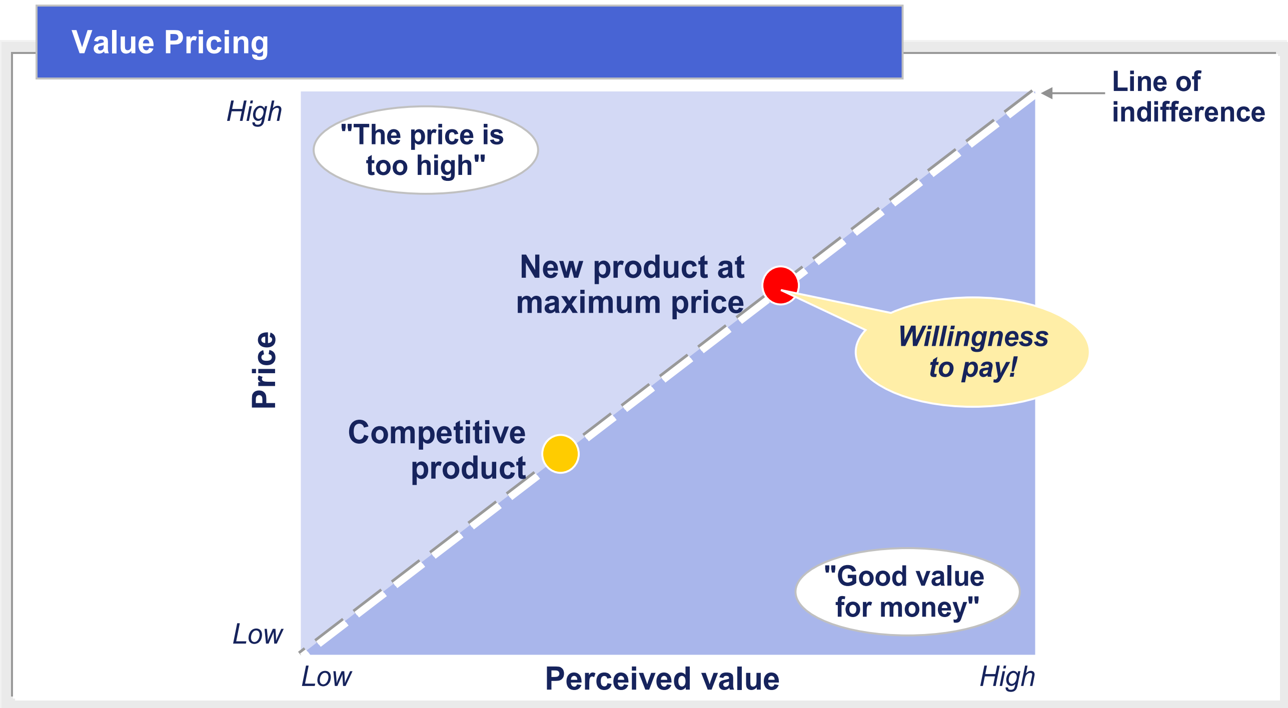

Figure 3

systematic pricing methods, binding and easy rules for the sales forces and sophisticated incentive systems.

Further Marketing and Sales Methods

So far so good – but pricing is only a module of a whole toolbox to increase profitability with respect to sales and marketing methods. Within this framework there should be other strategic methods mentioned such as value proposition, value pricing and target grouping whereas operative methods are complexity management, key account management, sales force effectiveness and transactional pricing.

Appendix 1

The pricing survey

Arthur D. Little and the Warwick Business School conducted a pricing survey with the participation of 75 Business Unit Managers, Sales and Marketing Managers of European chemical companies. The survey addressed topics such as the relevance of pricing, value pricing and transactional pricing. From the consolidation of data two main problem areas were identified being topical to the chemical industry: innovation and customer value management. While innovation serves in most cases as the answer how to maintain the current market position, customer value management is considered as a method to structure the company's customer portfolio according to profitable and less profitable customers. Furthermore it turned out that pricing is not the most relevant agenda point of top-management, obtaining relevance only if business success remains far behind expectations.

It seems curious: 59 % of the survey participants the sales departments have binding rules and guidelines for determination of prices. On the other hand 53 % of the managers feel that they are lacking customer-relevant information for their willingness-to-pay for. Even less informed are the interviewees concerning the profitability of their customers: 39 % do not know sales contribution of their customers. However, the chemical industry is about to change its mind: although up to now 73 % categorize customers with respect to strategic importance and only 28 % with respect to contribution margins, the survey found that in the future 48 % of the participants will take contribution margins into stronger consideration.

Most companies offer chemical products as well as services: 82 % of the participants have additional services such as warehousing or 24-hour-delievery service in their portfolio. Critical to this picture is the finding that the willingness to pay for these services is very limited: 21 % are not willing to pay and 57 % only partly.

The conclusion from these results is that price calculation is a rather unsystematic process in many companies. As many as 59 % of the respondents calculate "as the competition", only 22 % "value oriented" and 19 % on a "cost-plus" basis. This is a remarkable finding keeping in mind that the most respondents are very conscious about the key differentiators of their own products – obviously not successfully translating them into money.

Appendix 2

Ten golden rules – from a successful pricing initiative with the BASF AG:

The BASF AG was one of the first enterprises in the chemical industry that conducted a pricing initiative very successfully. From this initiative ten golden rules were extracted:

1. Visibility and engagement of top-management
2. Simple and easy guidelines and principles
3. Provide easy-to-use electronic tools that help the sales force identify and put a price on customer value
4. Interdisciplinary project organization (sales/ marketing/ SCM/ IT)
5. Exact definitions of rules and responsibilities
6. Create value creation communication plan by top management
7. Strengthen sales force's role as a partner of the customer

8. Align incentives for marketing and sales with pricing objectives
9. Train/coach sales force in guidelines, tools and negotiation skills
10. Sustainably establishing value principle by organization development

Appendix 3

In the pricing diagnostic we assess areas of improvement potential along the following dimensions: pricing objectives (profit, market share etc.), current pricing practices (cost-plus etc.), value based pricing, inferring customer valuations and price sensitivities, tools used for evidence based pricing, competitive analysis and market management, incentives, knowledge management, monitoring and control systems, negotiation techniques.

Key questions to diagnose the pricing and negotiation "as is" situation are included on the next pages.

A Pricing diagnostic

1. What are the company's **goals** in certain segments (e.g. regain share, long term profitability, obtaining critical mass to fill capacity) and how does **pricing contribute to achieving these goals**?
- Is the **goal realistic** in view of competitive reactions? This is particularly important in low growth market segments where differentiation opportunities are relatively limited, especially given the considerable excess capacity (over 30 %).
- How to set **correct pricing objectives** to achieve this goal? There are typically very few companies that manage to gain market share through pricing alone. The ones that appear to be able to do so (e.g. Dell Computers) tend to have some underlying low-cost value chain that cannot be imitated by competitors.

2. Analysis of current pricing practices (**cost-plus, formula, list price, competitor driven, customer driven**)
- Describe the typical price setting process, who is involved, what analyses are performed and which steps are sequentially taken?
- How is the effectiveness of current pricing measured?
- What is the frequency of price changes and frequency hereof?

3. Value-based pricing (differentiated pricing) and inferring customer valuations
- In what way are prices differentiated over segments/ individual customers
- What does the price/ customer plot look like (and the customer profit margin/ customer sales volume plot)?
- How does the company understand customers' valuations (willingness-to-pay) and how does the company identify how these valuations differ across segments?
- How does the company know how to influence/ raise that willingness to pay a price that reflects the product's true value?
- Which lessons are learned so far from differentiated pricing?
- Do competitors differentiate their pricing towards their customers, if so how?

4. Evidence-based decision making
- Does the company maximally extract the information from the data to estimate price elasticities (and hence optimal prices) and to extract higher prices from certain individual customers?
- What tools are used in the pricing process?
- Which data is collected to facilitate the pricing process?

5. Competitive analysis and managing competition/ market management
- How does the company deal with **entry threats**? With price cuts by competitors?
- Which tools of analysis does the company systematically use to **understand competitors' intentions** (and, as a result, e.g. avoid price instabilities) **and predict competitor behavior**?
- What type of **competitor information** does the company systematically collect to do so?

- Which tools of analysis does the company systematically use to manage competition (and to **influence competitor behaviour in the company's favour**)?
- How does Company **signal** its intentions to the market place?

B Negotiation diagnostic

1. Alignment of company goals and incentives for sales people

- What are the incentives for sales people (what is their bonus or sales credit based upon (volume of contracts, total sales, profit margin per customer, total profit contribution, knowledge sharing on competitors/ customers/ key accounts)?
- How is sales monitored and controlled?
- Are walk away values put in place and what is the authorization procedure?
- Are these systems and procedures in line with the company's pricing objectives?

2. Negotiation techniques

- What are some of the common pitfalls in negotiation strategy that sales people are trained to avoid?
- Conversely, do sales people get strict negotiation guidelines? If so what are some of these guidelines (to do's)?
- Which tools do sales people use to perform an in-depth analysis of difficult sales situations (game theory, role plays, etc.) and to come up with a negotiation strategy?
- Does the preparation for a negotiation include questions like: how to set the initial offer, how to respond to an initial offer of the buyer, how to frame the negotiation in terms of the benefit of the solution one wants to sell, how to identify and how to make trade-offs?

INSTRUCTIONS TO AUTHORS

In the following we want to present important instructions to authors. More information can be found on the internet at *www.businesschemistry.org*. If you should have any further questions, please do not hesitate to contact us at *info@businesschemistry.org*.

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  2. Cooper, R. G., Edgett, S. J., Kleinschmidt, E. J.,(2001), *Portfolio Management for New Products*, 2nd Ed., pp 9-13, Perseus Publishing, Cambridge, USA

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TABLES AND FIGURES

Tables should be numbered consecutively, have titles and sufficient empirical detail in a legend immediately following the title. Each column in a table is required to have a heading; abbreviations should be defined in the legend.

Figures should have titles and explanatory legends containing sufficient details to make the figure easily understandable. Numbers, letters and symbols used have to be sized appropriately. The abscissa and ordinate should be labelled clearly.

COMMENTS

If you have any comments on articles of the previous issue you are very welcome to send them to us as a separate submission. The comments are revised only by an Executive Editor and might be published in the next issue if they suit the academic discussion.

THANK YOU FOR YOUR CONTRIBUTION!

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