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Letter from the Editor

Exploring the wide field of business chemistry

As frequent readers of the Journal of Business Chemistry will have realized, our journal tries to cover all facets of this broad field. In the past four volumes we have presented topics as diverse as intellectual property in the pharmaceutical industry, incentives for employees in the chemical industry, the human side of innovation, futuring in the chemical industry, heterologous proteins for biopharmaceuticals and the use of renewable resources. Before we will relaunch our journal with a whole new layout for our 5th volume we are happy to conclude this year with a wide selection of topics that resembles very well our interdisciplinary field.

The first article “Channel Management in the Chemical Industry - Selecting the Right Option” deals with channel management and the shift in the priorities of chemical companies. What used to be all about producing new materials and being the first mover has (at least in part) made way for a focus on how to give the customer what he wants the most efficient way. The article closes with an overview of the situation of the European chemical distributors.

In “Testing Costs and Testing Capacity According to the REACH Requirements – Results of a Survey of Independent and Corporate GLP Laboratories in the EU and Switzerland” a study is presented that focuses on the prices for laboratory testing services and testing capacity in nine of the major European chemicals producing countries. These testing prices and sometimes even more importantly the capacities might pose a serious problem to those chemical’s producers that will have to deliver test results to the European Union under the new REACH regulation very soon. On the other hand, laboratories being able to conduct the required tests at a competitive pricing should be able to substantially increase their income.

Not formalized methods but the individual level is the main topic of the third article “Enthalpy Change: Firing Enthusiasm for Learning”. It examines how metaphors play a key role in conversation and the author draws an interesting comparison between human conversation and the thermo-chemical concept of enthalpy change. Anyone interested in human interaction and effective learning will get insights into a whole new approach to leading conversations.

In the last article “Chemical plant engineering projects – Customers around the world prefer cutting-edge technology “Made in Germany””, an overview of current developments in large industrial plant manufacturing for the chemical industry is given. It concentrates on developments and reasons alike.

We would like to thank all authors and reviewers for their contribution to this selection of interesting themes. Now enjoy reading the third 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

Channel Management in the Chemical Industry - Selecting the Right Option

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Abstract: Channel management was not until recently the chemical manufacturers' main concern. Their main priorities were to manufacture and innovate. It was only in the nineties that the marketing imperative prevailed and that cost efficient channel management processes were put in place. Producers facing a tougher competitive environment became aware of the importance to serve well their customers through direct and indirect channels. These channels adapted themselves to the growing needs of demanding customers who are seeking high quality and competitive products and services. In this article, we will highlight the relationship between producers' channel management and marketing strategy, selecting and managing the right market channel and finally the main challenges facing European chemical distributors.

Channel management is linked to corporate strategy

The importance of channel management is shown in figure 1. Marketing strategy covers the areas of market positioning, sales and order management as well as channel management processes which can be properly implemented when the supplier has already segmented its customer mix by size and needs, defined its supply chain processes, its IT programs and its order management processes. On this basis, the management of key accounts or A customers, medium size or important B accounts and C customers to be transferred and managed by distributors become transparent in the chemical, like in other industries.

The management of small and medium size customers is justified by these customers needs as they require more technical and commercial assistance, a wide choice of chemicals in small lots as well as specific services related to bulk chemicals, such as blends and formulations, packaging and drumming, returnable containers, recycling and disposal of used chemicals. The range of products and services required by these customers generally exceeds most manufacturers' capabilities and justifies the important role of chemical distributors.

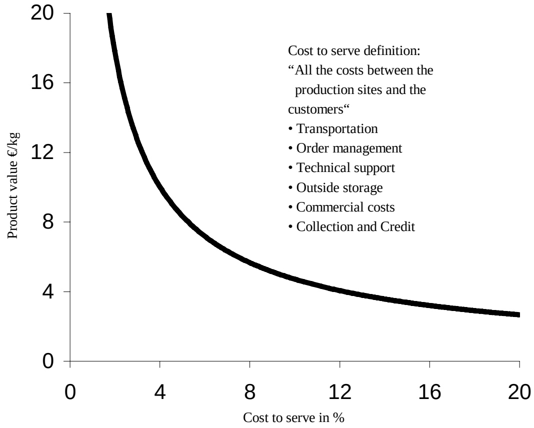

Figure 2: Producers' cost to serve assessment (source: DistriConsult)

In addition, in a tougher competitive environment, chemical manufacturers became aware the cost to serve importance. The cost to serve is the sum of all external costs which exist

Figure 1: Channel management is linked to corporate strategy (source: DistriConsult)

between the producers' sites and the final customers. As is shown in figure 2, the higher the value of the chemical sold, the lower in % is the importance of the cost to serve. By contrast, the lower the value of the chemicals, the higher is the relative importance in % of the cost to serve.

Consequently, chemical distributors have a relatively high market share of the lower value inorganic and organic liquid chemicals and a smaller share of the higher value fine and specialty chemicals which many producers prefer marketing themselves. Some European specialty and fine chemicals producers wish to retain the value of branded differentiated chemicals which they fear could become commoditized when sold through indirect channels. Some domestic producers use indirect channels for their products on overseas markets and sell directly or through controlled or fully owned distributors in Europe. An interesting example in that respect is BASF who markets their specialty chemicals through their in house BTC distribution company.

In the past years, distributors owned by chemical producers were sold to specialized distributors and mostly disappeared in Europe, as such distributors are often dominated by their owners' commercial priorities. They prefer selling their own in house products in priority to selling third party chemicals. An interesting example in this respect exists in polymer distribution where distributors which are owned by compounds and master batches producers are somehow outperformed by specialized polymer distributors. The expanding importance and contribution of chemical distributors in Europe and overseas is explained by the producers' necessity to reduce the cost to serve, to serve well the smaller customer segments and to grow sales.

Choosing and managing the right channels

Once a producer is convinced that managing themselves small and medium size customers is a costly and inefficient proposal, he faces the daunting task of having to choose and select the right channels.

These are important decisions which are on a short term basis almost irreversible. Therefore the channel selection process is a strategic process which requires an objective and professional approach. It must be implemented keeping in mind the overall corporate and marketing strategies as well as the customers' needs. Too often, those important channel decisions are taken with limited market knowledge and are wrongly based on internal requirements. The approach defined in 1993 by Northwestern University Professor Louis Stern is still up to date.

The recommended approach focuses initially on a clear understanding of end user needs, the supplier positioning and offering and competitors channel strategies. The existing channel network is compared with the ideal network. Once the channel options are defined, the optimal or achievable network is put in place.

Most producers are more or less following a similar approach based on their own selection criteria which are specific to bulk, specialty and fine chemicals. The indirect channel selection criteria tend to generically cover the following

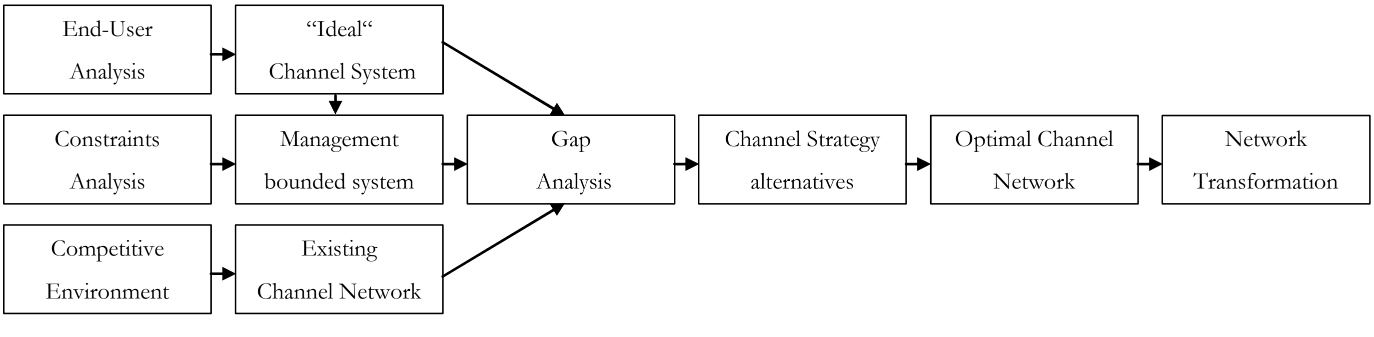

Figure 3: Channel Network Restructuring Professor Louis Stern's recommended approach (source: Louis Stern's analytical approach European Management Journal 1993)

aspects, namely environmental compliance based on REACH and Responsible Care, market or industry coverage, financial stability, resources available for growth, product portfolio, specific services and expertise available, ERP/CRM systems and quality management processes in place. According to the market to be served, it is wise to rank each channel option according to an objective rating process which measures the target distributor performance in relation to the defined selection criteria.

Once, a professional and objective selection process is put in place, the quality of the channel network tends to match the supplier's expectations for market growth and cost efficiency. Afterwards, it is common practice to put in place a defined and transparent channel performance monitoring process to reach jointly defined goals and objectives.

Channel challenges in the chemical industry

We identify four major challenges facing the European distributor industry namely REACH implementation, the growing role of private equity investors, the differentiated market structure for bulk and specialty chemical distributors and new rules on information exchange between suppliers and distributors. These four challenges are impacting significantly the European distributor scene.

- REACH compliance and implementation is one of the major challenges facing chemical distributors. They will gradually need to register themselves, their imported chemicals, as well as their "in house" blends and formulations. For some specialty distributors, this may represent a significant share of their sales and an additional cost to bear, which in some instances may not be in relation with the volumes transacted. Blends and formulations, particularly in the fine chemicals and life science areas are an additional sensitive area which will increase the operating costs of the distributors involved in those sectors.
- Among the top six European distributors, four are already owned by private equity investors who are attracted to this sector by high cash flows, limited financial risks and so far profitable exit prospects. Private equity owners are primarily focusing on cash flow generation and tend to favour the reduction of working capital, namely inventory, customer credit and staff costs. For this purpose, they tend to factor or sell the customer invoices, reduce credit and

Company	2006 Sales €M	Source	Ownership
Brenntag	3.400	Company report	*BC Partners (July 2006)*
Univar	1.717	Annual report	*CVC (October 2007)*
Helm	745	www.helmag.com	Private
Azelis	742	Company report	*3i Holdings (January 2007)*
Biesterfeld	640	www.kompass.de	Private & Warburg
IMCD	550	Company report	*ABN Amro Equity (June 2005)*
Omya	520	DC estimate	Private
Caldic	505	Company report	Private
Quimidroga	500	Company report	Private
CG Chemikalien	370	DC estimate	Private

Table 1: 2006 European Distributor ranking

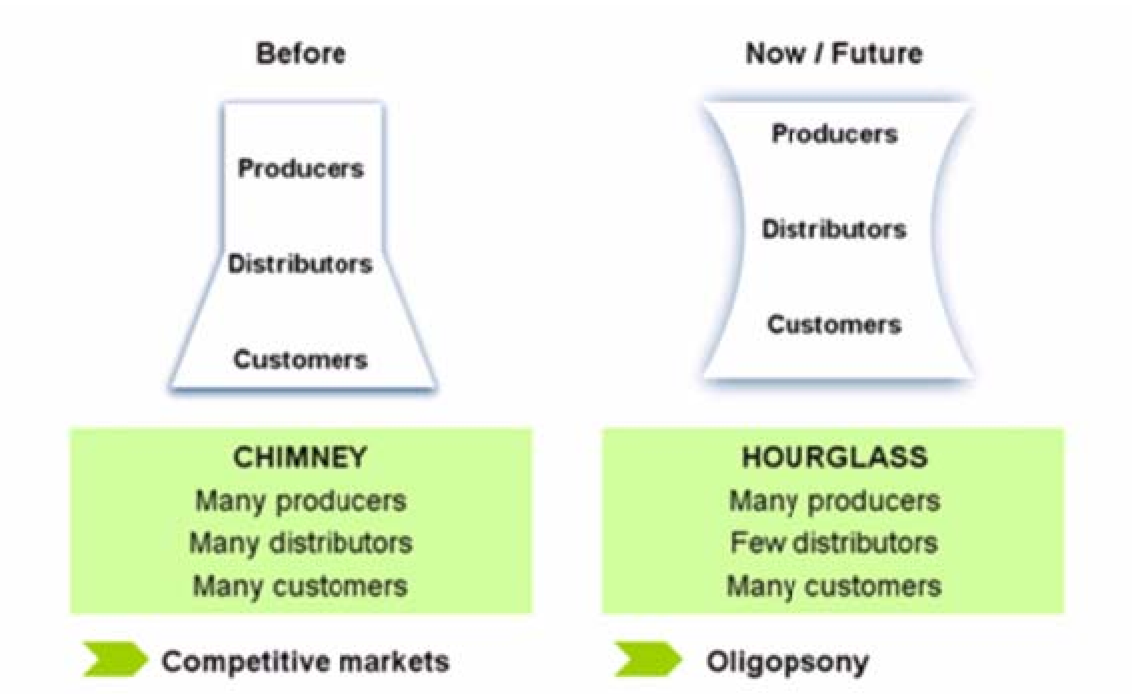

Figure 4: Bulk chemicals distribution (source: DistriConsult)

monitor closely inventory levels. Distributors who have more flexibility are often in a position to gain market share at the expense of financially rigid distributors. Privately owned private equity investors are keen buyers of distribution companies to reduce competition and to increase the value of the companies they own. Their preferred targets are high cash flow generating and asset rich distributors who offer good synergies with their existing assets. For such companies, they are ready to pay top multipliers in excess of 9 to 10, as the recent battle for the control of CHEMCENTRAL between Univar and Brenntag illustrates it well.

- As a result of the ongoing market consolidation through M&A, the number of bulk chemical distributors is reduced and the available channel options for bulk chemical producers is limited in each European country to a maximum of five or six distributors who together hold more than eighty percent of the relevant bulk chemical markets. For specialty chemicals, the options are wider and the existence of "oligopsony" or reduced market options may only occur on some niche industry segments where the number of specialist distributors is limited like in metal treatment, cosmetology or oil and gas. Figure 4 illustrates well the market structure of bulk chemical distribution.
- The EU competition rules introduced in 2001 are now being fully implemented. From a legal standpoint, distributors operate and compete on the same markets than their suppliers. Consequently, producers are not allowed to exchange pricing and customer information with their distributors. They need to operate commercially independently from one another. Suppliers are not allowed to restrict sale territories or to impose supply exclusivity. In the near future, it is expected that an additional set of rules will be introduced in order to prevent vertical and horizontal competitive restraints. This will make chemical markets more open and more competitive for the benefits of both suppliers and customers. In addition, all distributors will have to implement stricter governance guidelines to ensure full legal compliance within their organizations.

Conclusion

In conclusion, chemical distribution which followed until recently a reasonably simple model based on marketing domestically produced chemicals and margin monitoring is changing its model to become even more efficient and more professional in managing complex environmental and legal rules. It is also becoming more global in its search for new markets and supply sources. The growth and profit opportunities for distributors are immense; however fewer chemical distributors will reap the benefits of this market expansion, due to the need to comply with ever increasing legal, environmental and supply complexities.

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Research Paper

Testing Costs and Testing Capacity According to the REACH Requirements – Results of a Survey of Independent and Corporate GLP Laboratories in the EU and Switzerland

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Abstract: This study focuses on the prices for laboratory testing services and testing capacity in nine of the major European chemicals producing countries. The purpose is to bridge the existing gap of a representative study on test prices and the available testing capacity. At the core are seventy-six test categories, in particular toxicological and ecotoxicological tests as required by REACH, the EU Chemicals Policy Review. The price and capacity information was gathered by a survey of twenty-eight independent and corporate laboratories in the second half of 2004. The survey aimed at finding out minimum, average and maximum estimates of costs/prices and the available average and maximum testing capacities. The data exploration has shown a considerable variability in the prices for single tests. For reasons of completeness an overview of the testing cost for a registration according to the four work packages of REACH is provided. The most difficult issue was the estimation of average and maximum testing capacities. Surprisingly the large laboratories supply with 96.5% the vast amount of the total capacity available for testing chemicals in the nine European countries the survey has covered. A complete set of tables and figures representing detailed price and capacity information is available upon e-mail request to the author.

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Introduction

An effective system of chemicals control in the EU calls for very detailed information. Although a number of surveys is available no representative and detailed survey on testing cost as required according to the REACH proposal is at hand. Neither is there a survey on the available testing capacity in the EU. The most recent study on testing cost was published in August 2004 by BAuA--the Notification Unit according to the Chemicals Act at the Federal Institute for Occupational Safety and Health in Germany [1]. Their survey is based on the requirements for the notification of new chemical substances. The notification of new chemical substances in the EU requires specific test data to be provided by the notifier of the new substance. The testing requirements depend on the volume of the substance marketed per annum. The EU regulation distinguished three main categories, that is the “Base Set” of information, “Level 1” data, and “Level 2” data [2]. BAuA has tried to determine the testing cost for these three categories. However, it does not cover the complete set of test as required by the REACH proposal, which can be seen in appendix 1. A current overview of studies on testing costs is provided in a study of the German Federal Environmental Agency [3].

This study is to bridge the gap of a representative study on test prices and the available testing capacity. The study seeks to establish a statistical basis for a standard price for the single tests as specified in the REACH proposal by exploring the existing price variability. For the testing laboratories offering their services to a broader market, it is the net price charged to their customers. And, for the company labs, the standard price is a market-oriented transfer price, which they would charge to their internal and external customers. Thus, this price comprises more than the actual or standard costs of a test. It includes all costs associated with the carrying out of a test, including rent, overhead, and centrally funded costs, as well as a profit margin. Thus, this price is a good indicator of the single market price for corporate laboratory services.

This study covers the tests as specified by the European Commission in their REACH proposal Appendix IV to VIII, dated 29 October 2003 [4]. In several cases the original REACH testing requirements are not specific. Therefore, we consulted a paper by Pedersen et al. [5] and experts from the testing laboratories, as well as the current literature [6]. This survey focuses on 28 laboratories and chemical companies in Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Switzerland and the UK.

In the next section of the article we briefly discuss a few methodological issues and describe the design of the study. The questionnaire and the sampling procedure is described in detail. In section three the results are presented and discussed. We focus on the variability of prices and its causes and the difficulty of quantifying the available testing capacity. Section four summarizes the major findings.

Method and data

Methodological considerations

We should start with a theoretical remark about market prices. The remark is based on microeconomic theory [7]. From a microeconomic viewpoint the price in a competitive market is given, as is the capacity. The market price is the price at which demand matches supply. The market for laboratory testing services can be regarded as a perfectly competitive market since it has many buyers and sellers, so that no single buyer or seller has a significant impact on price. In a perfectly competitive market a single market price will usually prevail. In case the market is not perfectly competitive different laboratories might charge different prices for the same test. This can happen when one laboratory is trying to win customers from its competitors, or because customers have loyalties to laboratories, in which case these laboratories can charge higher prices than their competitors.

Market prices are only revealed as the result of market transactions. For our study this implies checking market transactions regarding laboratory-testing services for the past several years. This procedural consideration was put aside during the pilot phase of the study because the laboratories could not afford to check for a representative sample of past market transactions in order to derive prices. The only way forward was to focus on the prices they would charge for their testing services. And, it is reasonable to assume that the prices for specific laboratory tests will be a good indicator for the market price.

Capacity for testing services is a subtle thing. Usually, for most products, long-run supply is much more price elastic than short-run supply. This because firms face capacity constraints in the short run and need time for capacity expansion, for example by building new testing facilities and hiring qualified staff. It could be that short-run capacity rises if prices rise sharply. The available capacity is based on the cost function of the specific laboratory for single tests and on the relationship to the market price. Such a cost function is a relationship itself between the cost of conducting such tests and the output of a laboratory. An important issue is how the structural factors of a laboratory affect this relationship.

Estimating the available capacity for testing services is difficult and one that is pivotal to the survey. Capacity is difficult to quantify for many reasons. Nearly all laboratories – be they independent or corporate laboratories – provide services to several industry sectors. Thus, only the total capacity available could be given. Estimation of capacity is further complicated by the large diversity of studies the laboratories offer.

Study design and data collection

The study was designed as a cross-sectional survey using a questionnaire. We focused on the EU countries with a large share of chemicals manufacturing volume and on Switzerland because this allowed the study to cover most of the independent and corporate laboratories in Europe. Therefore the study could produce representative results and remain manageable.

The questionnaire covered five major areas. The first column of the questionnaire included the numbering of the Appendix of the REACH proposal so that the tests were grouped according to their subject (see appendix 1). Under the column, "Test guidelines", the OECD and EC test guidelines were also quoted. Again, it should be mentioned that REACH is not specific in all cases.

The questionnaire included the following sections:

- General questions about the company/laboratory
- Identification of the substance/ Information on manufacture and use of the substance (3 items)
- Physical-chemical tests (16 items)
- Toxicological tests (28 items)
- Ecotoxicological tests (28 items)

The survey aimed at finding out minimum, average and maximum estimates of costs/prices, which were based on costs/prices of the past two years. Although one might doubt averages, they do reflect a "sensed" underlying distribution. Several factors are influencing the distribution. Among others these are the properties of the substances to be tested, unexpected events during the tests, and intermediate results; because they often determine the effort and inputs for single tests; and as such the costs/prices of these. That is the exact actual costs/prices could only be given when details on the substance to be tested are known by the laboratory. Moreover, the prices for the single tests do not include costs for dose range finding and for the development of analytical method.

The capacity to conduct testing as required by the REACH proposal is available from both the chemical firms and independent testing laboratories. The required tests need to be conducted in general according to the Principles of Good Laboratory Practice (GLP) first published by the OECD in 1982 and revised in 1997 [8]. This meant for our survey that all prices/costs needed to be based on GLP requirements. GLP is a quality system covering the organisational process and the conditions under which non-clinical safety and environmental studies are planned, performed, monitored, recorded, reported and archived.

The following nine categories show the areas of expertise in which laboratories might choose to specialise. The category numbers correspond to the official GLP numbering of these fields.

1. Physical-chemical testing

   These tests measure physical and chemical properties of substances like melting point, flammability etc.

2. Toxicity studies

   These studies assume that tests on animals can be used to evaluate the toxicity effects on humans. Examples are acute toxicity studies (oral, dermal, inhalation) and carcinogenicity studies.

3. Mutagenicity studies

   These are studies to explore the gene toxicity of substances, for example gene mutation studies like the Ames test.

4. Environmental toxicity studies on aquatic and terrestrial organisms

   Examples are short-term acute toxicity studies on daphnia.

5. Studies on behaviour in water, soil and air; bioaccumulation and metabolisation

   These studies explore whether and how substances remain in the environment. Examples are biodegradability and bioaccumulation studies.

6. Residue studies

   They are mainly applied to pesticides. Tests are made for all types of agricultural crops (from corn to hops, fruits and vegetables) as well as long-term soil degradation studies.

7. Studies on effects on mesocosms and natural ecosystems

   These are very specific studies for pesticides like Pond studies. Artificial ponds are used to test different concentrations of substances.

8. Analytical and clinical chemistry testing

   This is a special category to characterize laboratories which provide only the analytical part of testing services from categories 2 to 7. They are dealing mainly with biological materials.

9. Other studies

The compliance monitoring is organised at the national level. The responsible national agencies report on the monitoring results to the OECD GLP Office and to the corresponding office at the EU Commission.

The recent lists of GLP laboratories for the year 2003 mention that Germany has 159 laboratories, the UK 128, France and Switzerland 44 each, the Netherlands 36, and Italy 29. These lists include independent labs and corporate labs, which all conduct their testing in compliance with the GLP Principles.

We have used the lists of the GLP laboratories with their areas of expertise to define the parent populations to be considered. Besides the eight areas of specialization listed above there are certain industry-specific specializations. The products and industries the labs are specialized in include chemicals, pharmaceuticals, agrochemicals, food, biocides and environmental legislation. Thus we had to select on a case by case basis those laboratories specialized in testing chemicals. Based on our knowledge and the knowledge of experts we tried to identify all relevant testing capacity for chemicals in the surveyed countries. However, the approach remains arbitrary, mainly due to a lack of more detailed information on the sampled population. A disadvantage of this procedure is, that it makes no sense to calculate a response rate because of the necessary but judgemental selection procedure.

We discussed the issue and the criteria which laboratories to include in the survey with experts, in particular with the British and German GLP Offices. Several laboratories were easily dropped according to their name, which suggested a business other than chemicals testing. More important was a systematic screening of the indicated areas of expertise of the GLP laboratories. We could exclude the areas 6) residue studies, 7) mesocosms and natural ecosystem, 8) clinical chemistry (applied for the pharmaceutical industry) and 9) other studies. We contacted the remaining GLP laboratories by phone and asked whether they would like to participate in the CEFIC survey. The result was that 51 laboratories showed their interest in participating in the survey (see table 1). In the end twenty-eight of these laboratories responded, of which we could use twenty-six in our analysis.

Country	All labs		Participating labs		All participating labs	
	Independent Labs	Corporate Labs	Independent Labs	Corporate Labs	Number	Percent
Germany	14	5	9	2	11	39.3
United Kingdom	7	6	4	0	4	14.3
France	4	1	3	1	4	14.3
Netherlands	2	2	2	1	3	10.7
Italy	3	0	2	0	2	7.1
Austria	1	0	1	0	1	3.6
Belgium	1	1	1	0	1	3.6
Denmark	1	0	1	0	1	3.6
Switzerland	1	2	1	0	1	3.6
Total	34	17	24	4	28	100.0

Table 1: Sample of independent and corporate laboratories involved in the survey

The prices and capacity we asked for were from 30 June 2004. The author conducted the survey from August to December 2004. This long survey period has to do with the interest in including as many laboratories as possible. It also took a lot of effort for the laboratories to compile the requested information. We should mention that all of the large independent laboratories from the nine participating countries are included, with the exception of one.

We should also mention that there are only a few corporate labs remaining in existence; in fact we obtained data from only four corporate laboratories. There is an ongoing process – but seemingly terminated – of phasing-out corporate laboratories for toxicological and ecotoxicological testing (and also for physical-chemical testing). The process could be observed in all the participating countries, with the result that few corporate labs remain. If we take a representative sample of seventeen large European firms which are listed in the global top fifty chemical companies in 2004 [9] than only four of them still have their own significant testing facilities.

A separate issue is, that the relative number of participating corporate labs is considerably lower than that of independent labs. This is due to the fact, that corporate labs are mainly managing regulatory compliance issues using independent labs for testing services. These corporate labs belong to large chemical firms which keep nevertheless the GLP status for their labs, but do not provide extensive testing services. This was the main reason for them not to participate in our survey.

Results and discussion

Summary of data and analytic technique

The data exploration has shown a considerable variability in the prices for single tests. Three attempts were made to reduce the price variability of the sample. The attempts were based on the response pattern to the three requested prices. The responses show the following pattern of prices given:

- Average price
- Average, minimum and maximum price
- Minimum and maximum price (price range)
- Minimum price

The first and the second responses posed no problem for calculating the mean and median of the average price. However, the laboratories have sometimes chosen for the same reason a different response pattern. In cases of a broad range of prices for a particular test category some preferred to give minimum and maximum prices only whereas others preferred to give the average price instead. The problem was that about a third of the respondents gave only the price range or the minimum price. This information would be lost in a rigid calculation of the mean and median of the average price since these respondents would not enter in the estimation of the statistical parameters. Thus, three options were considered to substitute the missing average price: first to use the minimum price; second, to use the mean of the minimum and the maximum price; and third, to use both of these substitutes.

The reasons not to use these substitutions are the same that underlie the respondents' behaviour. The main reason is that there is a strong impact on testing costs related to the characteristics of the substance to be tested. For a number of tests then, no normal average price can be given. In these cases only a price range is meaningful. However, this depends on the substances a laboratory usually tests. And in effect, as the responses show, for some labs an average price is still meaningful, whereas for others only a price range or a minimum price can be determined.

We have experimented with all three approaches to substitute for the missing average price. In the end, however, we found no less price variability than analysing the original data with a number of average prices missing.

Due to the comparatively small sample size and to reasons of comparability we limited the following presentation and discussion of the single tests to mean and median values.

Analysis of prices

An overview of minimum, average and maximum prices:

Appendix 1 offers an overview of the means of the average prices for the single test categories. It also shows the number of laboratories that provided data on average prices. For the purpose of comparison we included the costs as surveyed by BAuA [1].

Test categories	**Min. price**	**Max. price**	**Avg. price**			
	Mean	**Mean**	**Median**	**Mean**	**CV (%)**	**Ratio mean to median**
v 014 - Development of analytical method	4,567	8,333	2,250	5,239	100	2.3
vii 5.20 - Viscosity	891	983	600	860	49	1.4
vi 6.8.1 - Assessment of toxicokinetic behaviour	25,818	74,803	1,823	33,041	218	18.1
v 7.1.1 - Short-term acute toxicity study on daphnia	3,386	6,135	3,500	3,742	53	1.1
v 7.1.3 - Short-term acute toxicity study on fish	3,949	7,336	3,500	4,193	58	1.2
vii 7.1.6.1 - Fish early-life stage (FELS) toxicity test	28,717	47,839	21,000	26,254	60	1.3
vi 7.3.1 - Adsorption/desorption sceening study(HPLC method)	3,521	2,980	2,600	3,878	96	1.5
vii 7.3.2 - Bioconcentration in (one) aquatic species,preferably fish	43,873	87,082	28,250	40,333	96	1.4
vii 7.4.2 - Effects on soil micro-organisms	10,311	7,513	6,913	11,765	81	1.7

Table 2: Selection of test categories with high price variability

Price variability and its causes:

We have measured price variability using two statistical parameters--the coefficient of variation and the ratio mean to median prices.

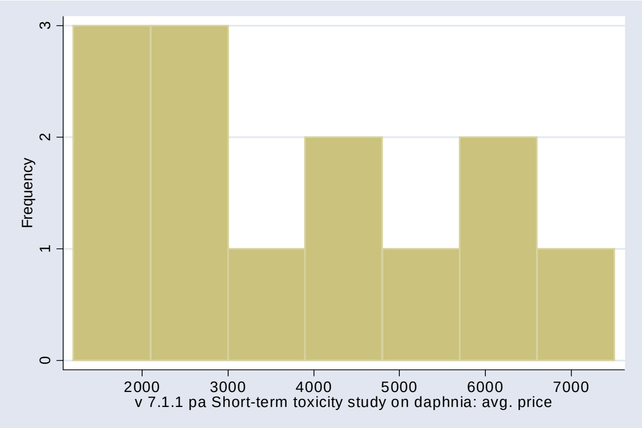
The coefficient of variation expresses the standard deviation as a percentage of the sample mean. This is useful because we are interested in the size of the variation relative to the size of the observation. Thus, we can compare the variability of a test price with a mean of 800 Euros to one of 80,000 Euros. The standard deviation alone would not allow for this possibility. Furthermore, the coefficient of variation is fairly easily understood and it incorporates all the relevant data. However, there is no general standard for an acceptable level of price variability. Thus, we had to fix a reasonable boundary.

The ratio mean to median of a sample of observations is a crude measure of the amount of variability (dispersion) in the distribution of the sample. It is commonly used to measure the skew of a distribution. And it is a simple way of identifying the test categories with the greatest variability in prices. A step-by-step screening has led to nine test categories with high price variability. Table 2 summarizes the statistical properties of these tests.

The table shows one extreme outlier in the test category “Assessment of toxicokinetic behaviour (vi 6.8.1)”. Out of the six responding laboratories four gave a very low price, one lab gave 7-times the median of the average price and the outlier lab 100-times the median of the average price. One possible reason for the majority of prices around 1,800 Euro might have to do with the actual legal requirements. In the OECD-Guideline 417 respective EU-Guideline B.36 expensive experimental testing is applied for a production volume beginning with 100 tonnes per annum. However the REACH proposal has lowered this boundary to 10 tonnes per annum. Thus, the majority of the labs might not have considered changes in the REACH testing requirements.

The outlier sheds as well light on three factors, which may have caused the variability of the prices. First, the prices may not reflect identical test offers, that is the products are not homogeneous and thus no single market price is able to prevail. This possibility could not be avoided in our survey because we could not ask for data covering the whole set of 30,000 chemical substances involved. Second, there are economic reasons, which include differences in input factors, efficiency of the laboratories, product portfolio and size, etc. Third, there is a miscellaneous category of reasons, such as differences in physical locations, that is when geographical differences are likely to lead to structural differences. E.g. laboratories which are located in areas heavily concentrated with firms of the chemical industry might have different demands for their testing services than laboratories in less concentrated areas. We discuss how these factors might have influenced the established price variability immediately below. An example of a test category with high price variability is “the acute toxicity study on daphnia”. Figure 1 shows the distribution of average prices as a histogram. This test uses daphnia which are small crustaceans, about 0.2 to 5 mm in length. They are used because they exhibit consistent responses to toxins in water. They are simple to be produced in large number. However, there are differences to do this as well as in the application of the experimental testing design. Figure 1 shows these differences and shows a price advantage of the small labs. The most obvious reason for price variability is that the properties of the specific test categories as outlined in our questionnaire were not perceived as unambiguous. The test categories left room for interpretation and diversity. The nine test categories in Table 2 illustrate that the prices surveyed may include different testing methods and services. We have tried to avoid this systematic bias by indicating the respective OECD and EU testing guidelines in the questionnaire. However, the testing guidelines themselves include a variety of testing options, which have implications on the cost of the overall test to be undertaken for a specific substance.

We should now consider the second reason for price variability, which has to do with economic factors. Among the few important economic determinants of cost are: size of the laboratory, prices of input factors (labour and materials), rate of output (i.e., utilization of fixed laboratory personnel and equipment), quality of input factors, size of the testing lots, laboratory technology, and the organization of the laboratory. One determinant on which we have information is the



V 7.1.1 – Acute toxicity study on daphnia		
Type of lab	N	Avg. price: Mean in Euros
All labs	13	3,742
Small labs	5	2,330
Large labs	4	4,900
Corporate labs	4	4,350

Figure 1: Analysis of a test category with high price variability

size of the laboratories. Our sample size is not large enough to test for differences in price means. We can, however, take a look at the actual differences in prices subdivided by size-classes. And a size-class distribution, which divides our sample well, is if we define “small labs” as having 1 to 100 employees and “large labs” as having more than 100.

We have tested for the difference in the means of the average price using only the small and large labs. We applied a Mann-Whitney U-test for the average price of 76 tests. In one case (1.3%) no lab offered the test and in eight cases small labs did not offer the tests (10.5%). In five cases (6.6%) we found a significant statistical difference in the averages prices between small and large labs at a 5%-level of significance. However, for the large majority of test categories, that is for 62 cases (81.6%) we found no significant statistical difference at the 5%-level in the in the price offered by small and large labs.

There are three points that we should mention. First, the small labs are not really that small. They average thirty-one employees. In comparison, the large labs average 386 employees (if we exclude one very large lab). The size of the small labs might be related to comparative advantage. E.g. the price advantages of the small labs might be due to advantages of specialization. Small labs generally offer a limited package of tests, which might enable them not to incur high fixed-costs. Second, we have no indication that the small labs have responded strategically, that is that they have responded to us with lower prices then they usually would charge. Third, the small labs supply on average only 3.5% of the overall capacity for testing services, for two thirds of the required tests the large labs supply the entire testing capacity. Due to this fact we have not explicitly included the mean values of the small labs into the estimation of testing costs for work packages according to REACH. However, they are implicitly included because we use the mean values for “All labs”, which the small labs have a strong impact on.

Estimation of testing costs for work packages:

For reasons of completeness we provide an overview of the testing cost for a registration according to the four work packages of REACH. The estimation used the mean values of the average and maximum prices for the single tests. The test categories are specified in the Appendix V to VIII of the REACH proposal of October 2003. The estimated test costs can be adjusted for special cases. We have added an estimated amount of costs for the development of analytical methods for the single work packages. The amounts are 20,000 Euros for 10-100t/y, 40,000 Euros for 100-1000t/y and 50,000 for >1000 t/y. It should be mentioned that the cost for the development of analytical method can vary enormously. The important point is, that our survey provides a very detailed and reliable source for actual prices for GLP testing services.

For our estimation of package prices we used, so to speak, three scenarios. First, the mean value of average prices of all labs and second, the one for the large labs. The former provides the low price level due to the relative low prices of the small labs it includes. The third scenario is based on the mean value of the maximum prices of all labs. The reason that in case of work package “100-1000 t/y” the maximum price is lower than the average price is that both price means include partly different labs with a different response pattern.

Analysis of capacity

Difficulty in quantifying capacity:

Laboratories which could perform the tests as specified in the REACH proposal belong to subgroups of the main group "74.30 Technical testing" of the European classification of economic activities, NACE. The subgroups are:

- 74.30.1 Engineering control and analysis,
- 74.30.2 Physical testing and analysis and
- 74.30.3 Chemical testing and analysis.

However, most of the Statistical Offices of the European Member States have only recently begun to collect information on this service sector, and they provide – if at all – only data for the main group 74.30.

To our knowledge and based on data downloaded from the Eurostat database in February 2005 we can conclude that statistical data on employment, cost, sales and the size distribution of laboratories since the year 2000 is only available for Germany and Italy for NACE 74.30. Thus, we cannot use official statistics for the purposes of our study. Furthermore, this data is too unspecific for estimating the available capacity for single tests. At best it could give a clue to make a guess about the overall laboratory capacity in the EU.

We have sampled the laboratories for participation in this survey based on whether they perform testing according to GLP. This basis for the sampling of the laboratories has led to a quite representative picture of the overall testing capacity for industrial chemicals. This is because all of the large laboratories have responded to our questionnaire, except one lab in the UK, which primarily conducts pre-clinical studies for the pharmaceutical industry. Nearly all of the medium-sized and small labs – from Belgium, France, Germany, Italy and the Netherlands – which provide testing services for the chemical industry are included.

Note that only very few of the labs with GLP status work for the chemical industry. We estimate that the share is less than 10%. Furthermore, we have included nearly all of the corporate labs. As already mentioned there are very few corporate laboratories left. The capacity estimation and questions we asked the laboratories were based on the following considerations.

Laboratory capacity is the capability to perform tests according to professional standards or guidelines. From an economic perspective the capacity of a laboratory for testing chemical substances represents the rate of operation that will yield the minimum average total cost of tests. Capacity in this sense is not fixed, but will vary with changes in the costs of the factors of conducting the tests. Capacity can be regarded as being optimal when a situation is achieved at which cost per unit of test is minimized.

The estimations of average and maximum testing capacities are still very difficult because they depend on a number of boundary conditions which impact on capacity management. It is particularly difficult for large laboratories with high capacity, which provide services to a number of industry sectors. Capacity is further complicated by the large diversity of studies they offer.

It is important to recognize that the maximum number of test per annum is the total theoretical capacity of a laboratory for each single test/study

	1-10 t/y	10-100 t/y	100-1000 t/y	>1000 t/y
Average price, all labs	56,360	279,838	799,562	1,582,616
Average price, large labs	70,407	292,269	916,340	1,610,910
Maximum price, all labs	81,120	409,602	872,724	1,966,189

Table 3: Summary of the estimated test costs for work packages of REACH Appendix V-VIII (in Euros per substance)

Required test package	Range of annual volume in tonne/year	Share of the total number of substances (%)	No. of required test packages based on 282 substances p.a.	
			EU capacity (excl. an import share of 53%)	EU capacity and Switzerland
Base set	1-10	57.8	77	98
Level 1a	10-100	8.5	11	14
Level 1b	100-1000	2.9	4	5
Level 2	>1000	0.6	1	1

Table 4: Estimation of the annual overall testing capacity according to the test packages for the notification of new chemical substances

type considering no other studies in the same category. Hence, the actual number of studies conducted – that is the average testing capacity – does not reach the maximum number but depends on the number of other tests of the same category and may vary considerably from year to year.

Laboratory management might imply short-term shifting of capacity from one test category to another or from one department to another; however, it does not increase capacity itself. We estimate that about one-half of the laboratory capacity might be shifted during short-term capacity adjustment.

For all these reasons, we have asked the labs to consider an estimation of the average and maximum number of tests based on the number of tests that they are able to conduct per year, as well as the number of tests they conducted in the past one or two years. The critical question certainly concerns the average capacity since this knowledge is needed to determine the number of studies the labs could reasonably run

No. of REACH appendix and test category	No. of labs	Total avg. capacity
viii 7.4.5 - Long-term toxicity testing on soil invertebrates	2	6
viii 7.6 - Long-term or reproductive toxicity to birds:	3	9
vi 6.7.2 - Developmental toxicity study (rabbits), oral gavage	3	12
vii 7.2.1.4 - Sediment simulation testing (for substances adsorbing to sediment)	6	12
viii 7.4.6 - Long-term toxicity testing on plants	2	12
viii 7.4.4 - Long-term toxicity testing on earthworms	7	16
vii 7.3.2 - Bioconcentration in (one) aquatic species, preferably fish	8	19
vii 7.4.2 - Effects on soil micro-organisms	7	19
vi 6.6.1b - Short-term repeated dose tox.: 28 days, inhalation (rats)	8	21
viii 6.6.3 - Long-term repeated dose tox. study (longer than 12 month)	10	21
vii 7.4.3 - Short-term toxicity testing on plants	6	25
vi 6.4.2 - In vitro cytogenicity study in mammalian cells (MNT)	3	28
vii 6.7.3 - Two-generation reproduction tox. study, oral gavage	11	28
viii 6.9 - Carcinogenicity study (rats)	11	29
vii 7.2.1.3 - Soil simulation testing (for substances adsorbing to soil)	7	29
viii 7.5 - Long-term toxicity testing on sediment organisms	6	30

Table 5: The 16 test categories with the lowest average annual test capacity in the major European chemicals producing countries

simultaneously over the course of one year. Furthermore, the labs need to be able to provide analytical backup for all these studies at the same speed as the in vivo part of the study and their capacity to do this currently would depend on the availability of the methods and the ease of set up.

Estimation of testing capacity:

To estimate the available testing capacity we used the information collected with our survey on average and maximum capacity. We estimated the overall capacity for the tests as required by REACH by totalling all the capacities of the individual laboratories. The information was collected for each test category, so that we could draw a very detailed picture concerning the overall capacity for single tests for the nine countries we have surveyed.

The data on the number of notifications of new chemical substances and their structural composition may be regarded as one proxy for the overall capacity in the EU for the testing of industrial chemicals. From the Website of the ECB, the European Chemicals Bureau in Ispra [10], we received the following statistical information summarized in Table 4.

Since 1994, an annual average of 282 new chemical substances has been notified. This average is based on the total number of new chemical substances. It includes imported chemicals to be notified, particularly from the USA (22%), Japan (18%) and Switzerland (13%). From the overall average of 282 substances we can attribute 47% to the testing capacity in the EU. For the EU and Switzerland this would be a share of 60%.

This number of test packages to be performed annually is obviously a lower bound and compared to our capacity figures very low. We have summarized the average and maximum testing capacity in appendix 2. The ratio of the maximum capacity to the average capacity available is about 2.5. Again, this indicates that the average capacity is a good indicator for the available testing capacity in the major European chemicals producing countries since it is reasonably lower than the surveyed maximum capacity. Appendix 2 also shows the average capacity for small and large labs. The maximum capacity is given for all labs.

A final consideration regarding available capacity should be stated. This has to do with the question of whether there might be severe bottlenecks for certain testing services. If we order the test categories beginning with the lowest average annual testing capacity we obtain the following picture.

Among these sixteen test categories with an average capacity of thirty or less tests per annum are three which already belong to the REACH Appendix VI testing package for 10-100 t/y, that is, where a considerable number would have to be undertaken if the REACH proposal would come into force. Six test categories belong to Appendix VII (100-1000 t/y) and seven to Appendix VIII with more than 1000 p.a. It is obvious that the actual testing capacity would become a bottleneck when REACH is implemented.

Conclusion

This study provides a contribution to the empirical foundation of the variability of prices for laboratory testing services. The analysis emphasizes many important questions related to competition in this segment of the service sector. In addition, statistical information is provided on the supply side of this sector, that is, information on the testing capacity in nine of the major European chemicals producing countries is given. Below is a very short summary of the major results and suggestions for further study.

1. The data exploration has shown a considerable variability in the prices for single tests and the impact of three factors causing this variability.
2. The first factor that has caused this variability is that the properties of the specific test categories as outlined in our questionnaire were not perceived as unambiguous.
3. The second factor is a bundle of economic determinants including differences in input factors and the size of the laboratories. A surprising result is that laboratories with 100 or less employees provide their testing services at a lower price level. However, this result is statistically not significant. It seems to be that small laboratories can

already achieve economies of scale in providing testing services by specialising in a limited portfolio of test categories. The large laboratories instead have to carry a substantial burden of fixed-cost due to their full-range testing portfolio.

4. In order to be complete an overview of the testing cost for registration according to the four work packages of REACH is given in Table 3.
5. The most difficult issue was the estimation of average and maximum testing capacities since they depend on a number of important factors, particularly on the portfolio of the offered and ongoing tests. Nevertheless, data on the available capacity for the testing of industrial chemicals is provided.
6. The large laboratories (defined as laboratories with more than 100 employees) supply 96.5% of the total capacity available for testing chemicals in the nine European countries the survey has covered.

For further study four suggestions should be considered. First, to increase the understanding of competition in this part of the service sector, particularly the understanding of the price variability and capacity supply by GLP laboratories, it is necessary to go into much more detail concerning the cost structure and the determinants of testing cost. This would imply considerably increasing the number of test categories over the seventy-six that we have used. Second, the range of testing cost is partly determined by the properties of the chemical substance to be tested. If a typology of substances could be developed to allow the clustering of chemicals according to testing relevant properties, then cost functions for testing cost could be constructed to derive more precise testing cost estimations. Third, the same applies to the development of analytical methods to be able to conduct the tests. Finally, the EU needs to further develop is official statistics covering the service sector. There is no excuse for the lack of detail in comparable industry sectors, particularly better data for NACE group 74.30.3 "Chemical testing and analysis" is needed. More detailed statistical data at this level would allow improved capacity estimations.

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Appendix

Appendix 1: Average prices for the tests as required by the REACH proposal: Overview by size of laboratory

Tests as specified in Appendix V-VIII of the REACH proposal	Test guide-lines: OECD / EU	No. of all labs	Avg. price: means in Euros			Large lab share of tot. capacity (%)
			All labs	Large labs	BAuA (2004) labs	
v 011 - Spectral data		10	2,094	2,626		40
v 012 - Analytical characterization		8	2,554	2,294		48
v 014 - Development of analytical method		9	5,239	9,500		85
v 5.02 - Melting point	102 / A.1	12	674	848	600	71
v 5.03 - Boiling point	103 / A.2	12	719	905	600	71
v 5.04 - Relative density	109 / A.3	11	657	829	600	72
v 5.05 - Vapour pressure	104 / A.4	8	2,779	3,211		84
v 5.06 - Surface tension	115	12	817	976	800	70
v 5.07 - Water solubility	105	11	3,813	4,508	3,900	78
v 5.08 - Partition coefficient	117 & 107	10	3,248	4,034	3,000	76
v 5.09 - Flash-point	A.9	11	809	896	800	75
v 5.10 - Flammability	A.10	9	812	912		77
v 5.11 - Explosive properties	A.14	9	2,284	1,885	3,300	76
v 5.12 - Self-iginition temperature	A.15 or 16	9	1,338	1,646	1,800	82
v 5.13 - Oxidising properties	A.17	9	2,144	2,611	2,700	74
v 5.14 - Granulometry	ECB Guidel.	6	1,328	1,318		92
vii 5.18 - Stability in organic solvents	105	5	3,496	4,427		76
vii 5.19 - Dissociation constant	112	8	3,216	4,663		76
vii 5.20 - Viscosity	114	7	860	1,281		66
v 6.1 - In vitro skin irritation/corrosion	430 & 431	4	1,645	1,893		98
vi 6.1.1 - In vivo skin irritation/corrosion	404	10	1,194	1,494	1,200	83
v 6.2 - In vitro eye irritation/corrosion		4	1,615	1,615		100
vi 6.2.1 - In vivo eye irritation/corrosion	405	12	1,343	1,650	1,100	86
v 6.3 - Skin sensitisation (LLNA)	406	8	3,959	4,668	3,200	88
v 6.4.1 - In vitro gene mutation study (Ames test)		11	3,174	3,204	2,900	91
vi 6.4.2 - In vitro cytogenicity study in mammalian cells (CA)	473	11	19,161	19,217	15,000	86

vi 6.4.2 - In vitro cytogenicity study in mammalian cells (MNT)	473	2	11,000	6,000		100
vi 6.4.3 - In vitro gene mut. study in mammal. cells (MLA)	476	7	16,603	15,644		98
vi 6.4.3 - In vitro gene mut. study in mammal. cells (HPRT)	476	6	17,283	17,933	13,000	86
vii 6.4 - Mouse micronucleus assay	474	9	11,268	11,785	11,000	90
viii 6.4.4 - Further in vivo mutagen.study: micronucleus or UDS test		4	18,898	21,864	22,000	100
vi 6.5.1 - Acute toxicity, oral route (rats)	423	10	1,474	1,639	1,400	79
vi 6.5.2 - Acute toxicity, inhalation route (rats)	403 / B.2	5	11,734	11,151	9,600	97
vi 6.5.3 - Acute toxicity, dermal route (rats)	402	10	2,011	2,470	2,000	88
vi 6.6.1a - Short-term repeated dose toxicity: 28 days, oral (rats)	407	10	49,390	55,360	40,600	89
vi 6.6.1b - Short-term repeated dose tox.: 28 days, inhalation (rats)	412	5	105,455	99,092	71,700	95
vii 6.6.1c - Further short-term repeated dose tox.: 28 days, dermal (rabbit)	410	6	49,550	48,175		93
vii 6.6.1d - Further short-term repeated dose tox.: 28 days, inhalation		1	99,000	99,000		100
vii 6.6.2 - Sub-chronic repeated dose tox. study: 90 days, oral (rats)	408	8	115,656	119,450	110,000	92
viii 6.6.3 - Long-term repeated dose tox. study (longer than 12 month)		6	372,000	382,500	394,000	90
vi 6.7.1 - Screening for reproduction/developmental tox.(rats)	421	8	54,597	54,129		96
vi 6.7.2 - Developmental toxicity study (rats), oral gavage	e.g. 414	7	63,100	76,550	68,000	93
vi 6.7.2 - Developmental toxicity study (rabbits), oral gavage	e.g. 414	2	92,500	.		67
vii 6.7.3 - Two-generation reproduction tox. study, oral gavage	416	8	327,975	313,967	250,000	93
vi 6.8.1 - Assessment of toxicokinetic behaviour		6	33,041	49,161	76,000	90
viii 6.8.2 - Further studies on toxicity of particular concern		2	101,250	101,250		100
viii 6.9 - Carcinogenicity study (rats)	451	7	780,357	787,083	767,000	97
v 7.1.1 - Short-term acute toxicity study on daphnia	202 / C.2	13	3,742	4,900	5,400	69
v 7.1.2 - Growth inhibition study on algae	201 / C.3	14	4,510	5,841	5,700	72
v 7.1.3 - Short-term acute toxicity study on fish	203 / C.1	12	4,193	6,203	6,100	75
v 7.1.4 - Activated sludge respiration inhibition testing	209 / L133	12	2,215	3,087	2,300	73
vii 7.1.5 - Long-term toxicity study on daphnia, 21 days	211	13	13,426	18,092	11,000	74
vii 7.1.6 - Long-term toxicity study on fish	e.g. 204	8	9,319	12,018		77
vii 7.1.6.1- Fish early-life stage (FELS) toxicity test	210	11	26,254	30,823	39,000	54
vii 7.1.6.2- Fish short-term tox. test on	212	7	10,238	27,413		21

embryo & sac-fry stages						
vii 7.1.6.3- Fish, juvenile growth test	215	8	16,462	21,466		91
vi 7.2.1.1 - Ready biodegradability	301	14	3,901	4,803	4,800	64
vii 7.2.1.2 - Simul. test. on ultimate degrad. in surface water	302	6	6,342	5,813	4,000	39
vii 7.2.1.3 - Soil simulation testing (for subst. adsorbing to soil)		6	35,792	43,583		76
vii 7.2.1.4 - Sediment simulat. test. (for subst. adsorb. to sedim.)		5	46,250	41,083		75
viii 7.2.1.5- Further studies on confirmatory biodegration rates	303A	4	17,325	40,000	20,000	72
vi 7.2.2.1 - Abiotic degradation: Hydrolysis as a function of pH	C.7	13	6,573	7,032	9,200	92
vii 7.2.3 - Identification of degradation products		1	2,000	.		100
vi 7.3.1 - Adsorption/desorption sceening study (HPLC method)	121	12	3,878	5,187	2,200	89
vii 7.3.2 - Bioconcentration in (one) aquatic species, preferably fish	305	6	40,333	112,500	122,000	74
vii 7.3.3 - Further studies on adsorption/desorption		7	19,634	26,060	20,200	78
viii 7.3.4 - Further environmental fate and behaviour studies		1	97,500	97,500		100
vii 7.4.1 - Short-term toxicity testing on earthworms	207 / L133	11	4,160	4,491	4,000	61
vii 7.4.2 - Effects on soil micro-organisms	ISO 11267	6	11,765	18,263		74
vii 7.4.3 - Short-term toxicity testing on plants	208	5	7,565	10,988	8,000	36
viii 7.4.4 - Long-term toxicity testing on earthworms	ISO 11268-2	6	8,580	6,289		56
viii 7.4.5 - Long-term toxicity testing on soil invertebrates		2	8,574	10,148		17
viii 7.4.6 - Long-term toxicity testing on plants		0	.	.		100
viii 7.5 - Long-term toxicity testing on sediment organisms		5	14,966	17,776		73
viii 7.6 - Long-term or reproductive toxicity to birds:	206	3	96,167	79,500		100
vii 9. - Descript. of the analyt. methods of detect. and analysis		1	750	750		100
- Vapour pressure, calculation					1,400	
- Vapour pressure, static, others					3,000	
- Vapour pressure, gas saturation					4,900	
- Flammability (solids)					600	
- Flammability (contact with water)					1,100	
- Subchronic inhalative, EU B.29					198,000	
- Fertility one generation, EU B.34					124,000	
- Metabolism study, OECD 417					150,000	

Appendix 2: Average and maximum testing capacity of small and large laboratories (in units of test per annum)

Tests as specified in Appendix V-VIII of the REACH proposal	Test guide-lines: OECD / EU	Avg. capacity					Max. capacity	
		Small labs	Large labs	All labs		Large lab share of tot. capacity (%)	All labs	
		Total	Total	N	Total		N	Total
v 011 - Spectral data		429	285	7	714	40	9	1,197
v 012 - Analytical characterization		269	250	8	519	48	8	855
v 014 - Development of analytical method		47	272	8	319	85	10	644
v 5.02 - Melting point	102 / A.1	190	462	12	652	71	13	1,168
v 5.03 - Boiling point	103 / A.2	190	462	12	652	71	13	1,168
v 5.04 - Relative density	109 / A.3	180	457	11	637	72	13	1,393
v 5.05 - Vapour pressure	104 / A.4	65	331	9	396	84	10	730
v 5.06 - Surface tension	115	196	452	12	648	70	14	1,423
v 5.07 - Water solubility	105	100	372	14	474	78	15	849
v 5.08 - Partition coefficient	117 & 107	113	372	14	487	76	15	857
v 5.09 - Flash-point	A.9	135	403	12	538	75	14	1,333
v 5.10 - Flammability	A.10	128	417	12	545	77	13	1,158
v 5.11 - Explosive properties	A.14	72	230	11	302	76	12	680
v 5.12 - Self-iginition temperature	A.15 or 16	92	428	11	520	82	12	1,125
v 5.13 - Oxidising properties	A.17	81	234	11	315	74	12	1,003
v 5.14 - Granulometry	ECB Guidel.	31	360	7	391	92	6	470
vii 5.18 - Stability in organic solvents	105	21	66	6	87	76	7	515
vii 5.19 - Dissociation constant	112	61	192	9	253	76	10	695
vii 5.20 - Viscosity	114	135	265	8	400	66	10	968
v 6.1 - In vitro skin irritation/corrosion	430 & 431	10	464	8	474	98	9	1,278
vi 6.1.1 - In vivo skin irritation/corrosion	404	145	698	12	843	83	13	2,028
v 6.2 - In vitro eye irritation/corrosion		.	425	7	425	100	9	1,138
vi 6.2.1 - In vivo eye irritation/corrosion	405	140	843	13	983	86	14	2,173
v 6.3 - Skin sensitisation (LLNA)	406	110	839	12	949	88	13	1,969
v 6.4.1 - In vitro gene mutation study (Ames test)		110	1,176	13	1,286	91	14	2,638
vi 6.4.2 - In vitro cytogenicity study in mammalian cells (CA)	473	35	224	12	259	86	13	464
vi 6.4.2 - In vitro cytogenicity study in mammalian cells (MNT)	473	.	28	3	28	100	3	40
vi 6.4.3 - In vitro gene mut. study in mammal. cells (MLA)	476	4	171	9	175	98	9	374
vi 6.4.3 - In vitro gene mut. study in mammal. cells (HPRT)	476	7	44	6	51	86	6	59

vii 6.4 - Mouse micronucleus assay	474	19	165	11	184	90	12	337
viii 6.4.4 - Further in vivo mutagen.study: micronucleus or UDS test		.	76	6	76	100	6	116
vi 6.5.1 - Acute toxicity, oral route (rats)	423	250	942	13	1,192	79	14	2,692
vi 6.5.2 - Acute toxicity, inhalation route (rats)	403 / B.2	6	180	9	186	97	10	394
vi 6.5.3 - Acute toxicity, dermal route (rats)	402	70	505	13	575	88	14	1,670
vi 6.6.1a - Short-term repeated dose toxicity: 28 days, oral (rats)	407	31	262	13	293	89	14	460
vi 6.6.1b - Short-term repeated dose tox.: 28 days, inhalation (rats)	412	1	20	8	21	95	9	64
vii 6.6.1c - Further short-term repeated dose tox.: 28 days, dermal (rabbit)	410	2	26	10	28	93	11	161
vii 6.6.1d - Further short-term repeated dose tox.: 28 days, inhalation		.	6	2	6	100	2	10
vii 6.6.2 - Sub-chronic repeated dose tox. study: 90 days, oral (rats)	408	13	154	12	167	92	13	251
viii 6.6.3 - Long-term repeated dose tox. study (longer than 12 month)		2	19	10	21	90	11	66
vi 6.7.1 - Screening for reproduction/developmental tox.(rats)	421	3	65	11	68	96	12	132
vi 6.7.2 - Developmental toxicity study (rats), oral gavage	e.g. 414	6	86	12	92	93	13	165
vi 6.7.2 - Developmental toxicity study (rabbits), oral gavage	e.g. 414	4	8	3	12	67	3	22
vii 6.7.3 - Two-generation reproduction tox. study, oral gavage	416	2	26	11	28	93	12	59
vi 6.8.1 - Assessment of toxicokinetic behaviour		20	177	6	197	90	6	388
viii 6.8.2 - Further studies on toxicity of particular concern		.	26	5	26	100	6	147
viii 6.9 - Carcinogenicity study (rats)	451	1	28	11	29	97	12	57
v 7.1.1 - Short-term acute toxicity study on daphnia	202 / C.2	143	368	14	536	69	16	1,290
v 7.1.2 - Growth inhibition study on algae	201 / C.3	122	360	15	497	72	16	1,091
v 7.1.3 - Short-term acute toxicity study on fish	203 / C.1	108	387	15	515	75	17	1,096
v 7.1.4 - Activated sludge respiration inhibition testing	209 / L133	83	233	14	318	73	15	774
vii 7.1.5 - Long-term toxicity study on daphnia, 21 days	211	23	80	13	108	74	14	236
vii 7.1.6 - Long-term toxicity study on fish	e.g. 204	17	57	11	74	77	12	194
vii 7.1.6.1- Fish early-life stage (FELS) toxicity test	210	14	20	12	37	54	13	126
vii 7.1.6.2- Fish short-term tox. test on embryo & sac-fry stages	212	25	7	10	33	21	11	137
vii 7.1.6.3- Fish, juvenile growth test	215	3	30	9	33	91	10	100
vi 7.2.1.1 - Ready biodegradability	301	167	317	14	496	64	17	1,169
vii 7.2.1.2 - Simul. test. on ultimate degrad. in surface water	302	25	16	6	41	39	7	172
vii 7.2.1.3 - Soil simulation testing (for subst. adsorbing to soil)		2	22	7	29	76	7	61

vii 7.2.1.4 - Sediment simulat. test. (for subst. adsorb. to sedim.)		1	9	6	12	75	6	30
viii 7.2.1.5- Further studies on confirmatory biodegration rates	303A	13	34	6	47	72	7	193
vi 7.2.2.1 - Abiotic degradation: Hydrolysis as a function of pH	C.7	30	361	15	393	92	16	681
vii 7.2.3 - Identification of degradation products		.	55	3	55	100	4	108
vi 7.3.1 - Adsorption/desorption sceening study (HPLC method)	121	40	318	13	358	89	14	560
vii 7.3.2 - Bioconcentration in (one) aquatic species, preferably fish	305	4	14	8	19	74	10	62
vii 7.3.3 - Further studies on adsorption/desorption		20	81	8	104	78	8	172
viii 7.3.4 - Further environmental fate and behaviour studies		.	20	2	20	100	2	35
vii 7.4.1 - Short-term toxicity testing on earthworms	207 / L133	26	41	10	67	61	12	283
vii 7.4.2 - Effects on soil micro-organisms	ISO 11267	3	14	7	19	74	8	91
vii 7.4.3 - Short-term toxicity testing on plants	208	16	9	6	25	36	8	77
viii 7.4.4 - Long-term toxicity testing on earthworms	ISO 11268-2	7	9	7	16	56	10	111
viii 7.4.5 - Long-term toxicity testing on soil invertebrates		.	1	2	6	17	3	75
viii 7.4.6 - Long-term toxicity testing on plants		.	12	2	12	100	2	25
viii 7.5 - Long-term toxicity testing on sediment organisms		3	22	6	30	73	7	80
viii 7.6 - Long-term or reproductive toxicity to birds:	206	.	9	3	9	100	5	116
vii 9. - Descript. of the analyt. methods of detect. and analysis		.	1	1	1	100	2	60

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Research Paper

Enthalpy Change: Firing Enthusiasm for Learning

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Abstract: The paper examines how metaphors play a key role in triggering individual emergence, involving the recognition of a new form, pattern, structure, organisation, model or concept, and then possible behaviour change. Individual emergence is thus of direct interest to the designer of learning systems. Enthalpy change, derived from thermo-chemistry, is mapped to human experience of conversation: within a group, between individuals and to conversations-with-self. Metaphors are also explored as driving agents for triggering personal change and for firing enthusiasm for learning. A model of individual emergence is presented based on metaphors in (1) conversation (2) other external stimuli including learning/training materials (3) internal thought processes. Practical ideas are provided for those involved in learning systems design. The need to provide appropriate metaphor as catalysts to engage the learner, and to sustain learning, is illustrated through example, as is whether specific catalysts are appropriate given the context.

The thrust of this paper, originally presented [1] to the International Society for Professional Innovation Management (ISPIM), has been adapted and extended for the reader's of this Journal.

Introduction

This paper examines how metaphors can be exploited to trigger individual emergence. It is adapted from a paper recently presented to the International Society for Professional Innovation Management (ISPIM) [1].

The model developed here is offered as guidance for those interested in planning and designing learning, and in stimulating behaviour change. To reduce semantic difficulty it is important to provide definition of the terms used. The word metaphor is interpreted broadly, and is assumed to be inclusive of the wide range of images, analogies, concepts, models, theories, and inputs from the outside world that we receive and interpret individually or collectively through our five senses. The term "emergence" comes from the systems science discipline; and is used here in relation to the process of learning and development that brings about future behaviour change.

The International Encyclopaedia for Systems and Cybernetics [2] has the following definitions:

- Emergence – the recognition by an observer of new form, shape, pattern, structure, organisation, model or concept
- Individual emergence – the recognition by an individual of a new order or level of their understanding or competence, or of adjustments to perception or values, which then leads to change in their future behaviour.

For individual emergence to take place, the following phases will be involved (1) exposure to, and recognition of, a new idea (2) internal reflection on that idea set against experience (3) test and acceptance of idea (4) behaviour change.

In practice the use of the terms "emergence" and "individual emergence" can blur, and an example will help to differentiate. Take the context of a junior manager and an appraisal session with their line-manager. During the session the junior manager may come to recognise a pattern of problems of their leadership style (emergence) in certain scenarios. Following training in models of leadership, the junior manager would hopefully demonstrate individual emergence in a capability to deal with a range of leadership scenarios, in that a new pattern of successful leadership outcomes emerge.

One issue is the extent to which individual emergence can be designed or planned, thus the topic is direct interest to the designer of learning systems.

The paper first makes a link to group emergence (learning within, and change in behaviour of a group). This connects to the author's earlier work [3] on a metaphor drawn from thermo-chemistry, namely enthalpy change, i.e., the change in internal energy of a system of chemical reactants. Enthalpy change can help to explain how some conversations ignite and sustain on-going interaction between participants so that their potential for creative synergy is maximised, and how other conversations flicker and die.

The paper then shows that the concept of enthalpy change can also provide useful insights on the potential for individual emergence. The enthalpy change metaphor provides the basic framework for considering problems of emergence, but metaphors also emerge as key driving agents for triggering personal change, or for firing enthusiasm for learning. A basic model of individual emergence is presented which assumes trigger categories arising from metaphors used in (1) conversation (2) other external stimuli such as learning/training materials (3) internal thought processes. The paper then discusses which of these categories of stimuli might be more/most/jointly powerful in triggering individual emergence in a range of contexts and gives some pointers for exploiting the ideas in learning design, and for workshops aimed at encouraging change.

Enthalpy change in chemical reactions

Many readers of the interdisciplinary Business Chemistry Journal will well know the concept of enthalpy change in chemical reactions. They will perhaps forgive me for providing a short description of the concept for readers who may be less familiar, and also, because my purpose is to highlight particular features of enthalpy change that can also serve as a metaphor for human interaction.

Bonding changes in some chemical reactions can release energy (enthalpy change) into the chemical system and sustain further reaction. The inherent stability of chemical compounds is because the atoms from which they are made are bonded together. The bonding itself involves energy, so the first step in a reaction between two chemical compounds is an input of energy to break the bonds that already exists. The second step is to make new bonds that will exist in the products. The amount of energy required to start a reaction is called the activation energy - it is simply the height of the "energy barrier" or "energy hill" to overcome the bonding of the first molecules to enable them to react. Figure 1 illustrates the enthalpy change concept.

Assuming the energy released from first interactions between molecules is greater than the activation energy (this is the case in the so-called exothermic reaction) then more molecules can react, and a chain reaction can occur. As the reaction develops, eventually the energy release may be sufficient not only to maintain combustion but also to release excess heat to the environment. The chemical chain reaction can occur if h_2 is greater than h_1.

It is also important to introduce the concepts of catalyst and reverse reaction. A catalyst is a substance that alters the rate of a chemical reaction but may itself be unchanged at the end of a reaction. They work in various ways but their purpose is always the same - to reduce the activation energy (h_1). Using a catalyst will allow reaction to proceed with lower energy input. There is another advantage to catalysts, as conditions arise where several reactions, which can lead to different end products, are possible. Catalysts can sometimes be found that are specific to particular reactions taking place. Using a specific catalyst**,** the reaction that produces the desired product can be enhanced at the expense of other possible reactions. This is an important idea for later discussion on learning design.

Some chemical reactions are reversible, particularly if the products from the reaction are still within the reactant mixture. The reverse reaction means that the products recombine to form the original starting ingredients. However the reverse reaction implies the breaking of bonds that have been made by the forward reaction and energy being diverted from the forward reaction.

Enthalpy change metaphor and group work

The description of chemical reaction provides only a partial explanation of what happens within a situation involving human inter-action say, in group work, or in a conversation. The participants will arrive with external bonds still partly intact. They will be pre-occupied and bonded to their social and professional culture. Hence the equivalent of activation energy will be required to be input to the group to break or loosen these bonds. Some form

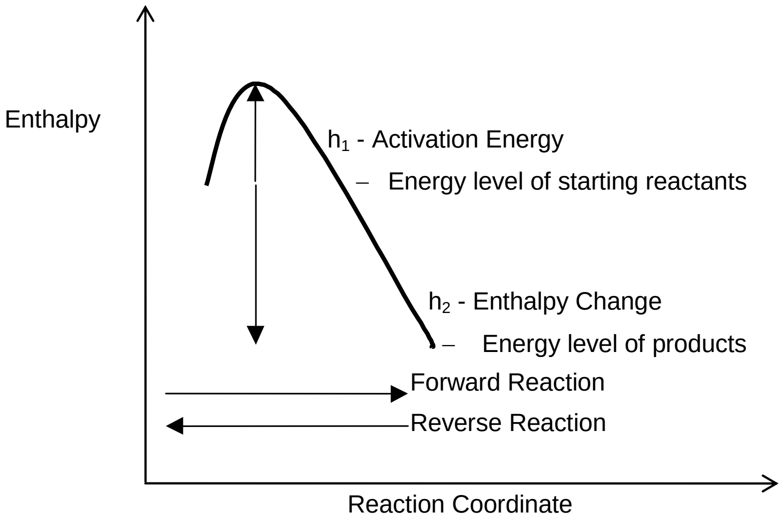

Figure 1: Enthalpy change

of spark must either be generated within the group or be brought in from the environment. The "wheelspin" which is a common experience in conversations can be seen as sparks which had inadequate energy to overcome the energy hill the group faced. But once the right spark has been found, and the group reforms bonds and works collectively, then energy is released - through enthalpy change - to enable them to interact further and "perform". As the group increases its bonding something akin to the chemical chain reaction is taking place. But something more dramatic will happen in the case of human interaction in that as the starting energies of the participants varies from day to day, not only are the activation energies different but so will the enthalpy changes. Thus any chain reaction which results appears to provide at least a partial explanation to what is usually described as the synergy of human activity systems i.e. the non-repeatability of group interaction and the capacity to produce unexpected results, which are sometimes very creative and positive, and sometimes the opposite.

Continuing the comparison of characteristics of chemical reactions with human inter-action, let us consider the role of catalysts in reducing activation energy, sustaining interaction and reverse reaction. A number of factors can operate individually and collectively as catalysts to reduce the activation energy necessary for conversation to start, for example:

- External environment - may reduce bonding to perceived constraints, and also be a source of inspiration. An "Away Day" - i.e. group work away from the office can be useful to loosen bonds to constraints of social and professional culture
- Internal environment: warmth, comfort, seating arrangements e.g. – a circle of chairs to encourage interaction; place symbolic empty chair in circle to represent those not present but who will be affected by any decisions made
- Circulation or tabling of ideas from input papers
- Opportunities to meet others informally beforehand
- Previously shared or recently emerging ideas
- Imposition of time pressures, or deadlines
- Exploit early opportunity to foster bonding by adopting a flexible style of introductions e.g. rather than self-introductions, form pairs for discussion and then have A introduce B, B introduce A. Encourage participants, if appropriate, to avoid ring-fencing themselves by quoting post and function e.g. "I am from the Accounts". Suggest they convey a more open description of what they or colleague might be able to bring to the discussion e.g. "My interests are X, Y and Z". A Japanese colleague of the author conveys his openness by introducing himself as simply as a citizen of Planet Earth.

Conversation largely takes place through sharing and offering metaphor, which reflects the basis of understanding, beliefs and values that the participants hold. As Gregory [4] has said "Conversation is nothing more – and nothing less - than the attempt to model the way in which we manipulate our metaphorical systems to construct shared meaning and thereby, come to agree with one another over what we understand". To sustain a conversation it is vital that metaphors that are shared are culturally and linguistically appropriate, and also possess structure, depth, and richness with an appropriate degree of familiarity and referencing for the intended purpose. In this way the metaphors serve as catalysts and triggers. For example, it may make no sense to refer to a "round table" to the Bushmen of the Kalahari Desert. The author experienced difficulty in using metaphor in a conversation between US and UK citizens. This was an attempt to convey the need for extreme secrecy, by stating we would need to behave like the Magic Circle. The metaphor was not understood, as there is no Magic Circle in the USA, that in the UK is the professional body which controls and licences magicians to perform professionally, and binds them to not telling non-members how tricks are done.

Also the use of inappropriate images as metaphor can be dangerous, and have a dark side, when used for persuasion, coercion and interpreted too far.

Conversation will be sustained only if the metaphors shared continue to provoke interest and the release of internal energy. The equivalent of a chemical reverse reaction will occur in the group if for any reason relationships in the conversation circle begin to break down. In effect energy is expended to break bonds, at the expense of maintaining the bonds so that energy is available for joint creativity. It follows that the group, or its facilitator, should monitor its behaviour for danger signs. The danger of bond-breaking within the group is likely to happen if any member of the group feels that they are not being given adequate opportunity to contribute, or their freedoms of expression, action or participation is being impaired in some way; or conversely that others are trying to dominate.

A comparison between the chemical reaction and human interaction led the author to propose suggestions for planning and sustaining an effective conversation [5]. A conversation in that sense is an extended form of group dialogue in the context of social systems design as proposed by Banathy [6], that also aims for maximum participation and maximum creative synergy.

Conversation

The context of conversation can vary enormously. The style of conversation proposed by Banathy is a potentially powerful opportunity for change in that it takes place over an extended period with many triggers being generated to sustain bonding and internal energy. Also this context involves willing participants who are generally open to new ideas and to the possibility of change, so that the activation energy required for the group to be productive is low.As Stewart [7] observes:

> "Conversation is the antithesis of debate in that it is not based on adversarial premises and does not polarise people. Participants realise that the winning of arguments is not the issue. It opens the discussion rather than channelling it into something that may be difficult to get out of. It enables "change of mind" to occur, without fanfare or fuss. It is the foundation of community building."

This approach can be usefully employed in workshop contexts. For example, in a business setting where there has been some conflict between departments because of difference in their professional culture. This may be the case in an R&D setting where say, the R&D engineers and finance office have clashed over speed of ordering and purchase of components to support tests and trials. The engineers have looked for a very rapid response to their requests for components, but finance want to place orders through an established system.

Not all conversations will begin in the ideal open way proposed by Stewart, indeed they may not even start, especially where there is a history of conflict or major cultural difference, or where there are fundamentalist views present. Cultural differences of this kind may be seen as a very high level of activation energy acting to prevent the formation of new bonds. Action research into conversation, for example for peace treaties, stresses the need to search for those visions which are common and transcultural rather for those issues which differentiate positions and are inter-cultural. Methods advocated are to be found in Bohm [8], and in Banathy and Jenlink (Eds.), [9]. These typically suggest a period of generative dialogue before strategic dialogue.

Shorter conversations whether open or adversarial, may have less effect but even within a short exchange, if metaphors offered by one person engage the interest of another, then individual emergence is possible. We also note the inevitability of unexpected outcomes arising through engaging with metaphors provided in conversation.

Mental Map and Perception Mask

Let us begin by considering how an individual develops a mental map of their experiences. Over time, this map is built up, revised and reinforced over time and experience, by the range of stimuli present in their environment, and in their own social and professional culture; e.g. through:

- Touch, taste, smell
- Sound
    - Spoken language
    - Music
    - Natural sounds
- Sight
    - Symbolic language
    - Written text
    - Mathematical and conceptual models
    - Diagrams
    - Shape, size, colour,
    - Art: drama, poetry
    - Story: fiction, selective facts, science fiction, myths and legends, fantasy
- Collective senses
    - Natural and man-built world

All these metaphors, particularly the images and story, provide the basis for individuals to understand and rationalise the external world around them. Over time this leads to a set of core values, beliefs and to a "perception mask", which taken together we can regard as "self". This mask can be an obstacle for change.

Exposure to any new stimuli in one's external world can be random e.g. unexpected recall or sight of a scene of outstanding natural beauty, or the recall or hearing of a remark by another. Opportunity for new stimuli may also be planned e.g. by travelling, embarking on a new course of study, or going to a lecture. If any subsequent new stimuli are of sufficient interest to overcome the activation energy required to produce a "conversation with self" and deep reflection, this too can lead to internal synthesis and transformation. We may call this creative synergy-with-self. If the interest and connection with triggering metaphors is sustained and strong enough, the creative synergy-with-self can lead to excitement and enthusiasm for learning and then to adjustments in the individual's perception mask and to individual emergence.

However, the non-repeatability of group interaction (because of variable enthalpy change) and the capacity to produce unexpected results, also applies to "conversation with self". The individual's starting energy varies from day to day, as will the impact of the trigger and the activation energy required to connect to it; thus the enthalpy change will vary. Thus the effects of the same trigger on an individual can vary, they are sometimes very creative and positive, and sometimes the opposite. It is clear from everyday experience that the same triggers on different individuals can potentially produce very different effects. This is a key issue for those who are involved in the design of learning systems (see below), which are usually intended to produce individual emergence.

Enthalpy change and individual emergence

Figure 2 shows a conversation between participants A and B, each with their own perception mask. A dialogue is illustrated as the simplest version of a group exchange. The diagram shows that if care is taken to trigger and sustain communication through catalysts and appropriate metaphors that are accessible to both, then temporary bonding and positive creative synergy can result. If appropriate transcultural triggers and metaphors are provided over a period then a deeper reflection – synergy-with-self can occur. This can then lead to a shift in perception mask and individual emergence in either or both A and B, i.e. there can be collective emergence.

Given the issues previously raised relating to cultural difference, it follows that conversation to achieve maximum creative synergy is a practice requiring considerable skill. In many contexts, say, where there has been family or work-based conflict, a skilled intermediary is required to sustain a communication aimed at resolution.

One research theme within systems science over the last 10-15 years has been linked to conversation design and practice, how to avoid conversation breakdown and how to disseminate the knowledge gained. The ideas in this paper are incorporated into the body of knowledge of this

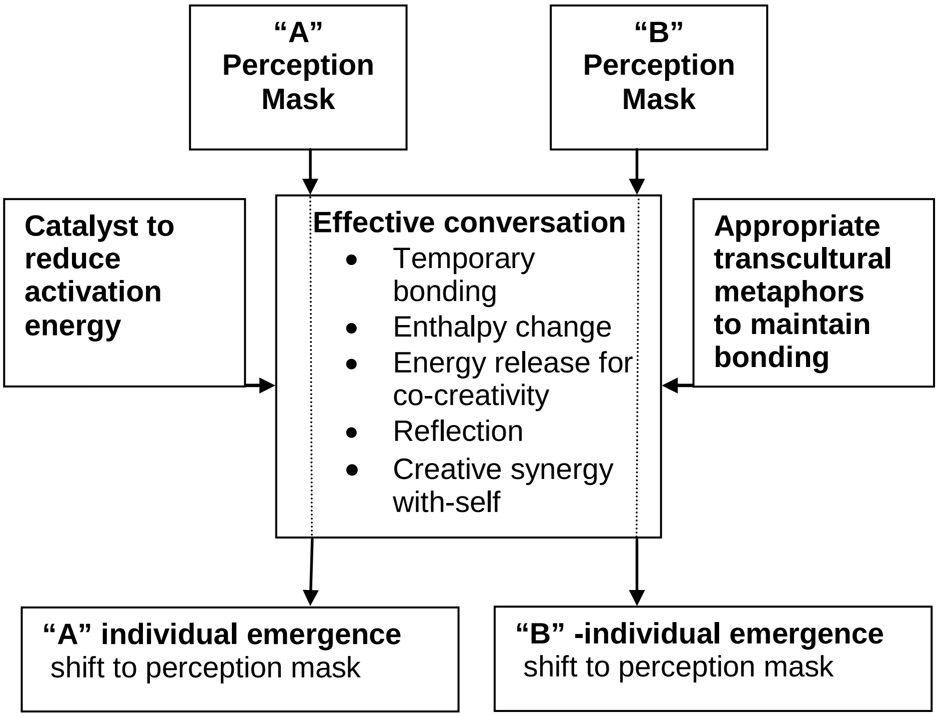

Figure 2: Enthalpy metaphor framework explaining emergence

"social systems design" activity, Banathy [6] (op cit), and in linked action research of the International Systems Institute [10]. This paper offers the opportunity to diffuse the ideas into a separate discipline area.

Exploring the model

The model proposes that individual emergence is possible through metaphors arising from 3 different types of source:

1. Conversation with others (as described above)
2. Other external stimuli
3. Internal thought processes (reflection).

These three constitute a system of sources in that they can act either singly or jointly, or sequentially, and might themselves be connected in certain contexts. Whatever the source, if the trigger is strong enough, a "conversation-with-self" may ensue, sometimes immediately or after a delay. The intensity of this may be strongest in (1) and least in (3), especially if the conversation is extended. This is because conversation with others involves two-way (or n-way) interactions, and potentially provides many and variety of triggers to sustain communication, to release energy to sustain reflection and thus adjust the perception mask to produce change within the individual. Clearly time and depth of engagement in conversation is crucial. There may be other factors at play.

In a case of (2), for example, if the input is via newsprint or other forms of printed material, the interaction is one-way. Thus careful design is necessary to ensure that attention of the reader is maintained and that necessary regular triggers are present throughout. The case of a newspaper is interesting in that it is designed to prevent emergence and change in the reader. We tend to buy the newspaper that tells us what we want to read and can be upset if our paper is not available when we come to buy it. This is because each day "our" newspaper typically reinforces our perception mask, and uses metaphors and images with which we are most familiar and content. This is because newspapers often support a particular political agenda so images will either reinforce our perception of our political persuasion as good, or reinforce the perception of the other side, as bad.

In the case of (3), emergence is least likely for most people by this source acting alone. Though this does not discount the possibility of occasional sudden extraordinary insight from within any individual; it is more likely within the creative artist or genius.

The context will lead to a variation in conclusions about which of the 3 components of the model: (1) conversation (2) other external stimuli (3) internal thought processes, may be more/most/jointly powerful in triggering emergence. Let us examine context through considering sources, whether the exposure to the source is planned or not, and the case of inappropriate triggers.

Design of learning systems

The range of potential stimuli in one's external world listed is enormous, and the impact of them will vary from individual to individual. Interestingly, the range of stimuli, which in one's own social and professional culture reinforce one's perception mask, are also available to learning designers to trigger emergence. The choice of which is clearly context dependent. The role of art-based metaphors can be crucial, in that new visions of alternative futures can be introduced to set alongside the story, poetry, myths and legends of the past.

We also recognise that one person might be moved to tears, another unaffected, or another laugh at the same image. However, this type of temporary individual emergence is of less interest, compared to an emergence that leads to permanent new thinking or behaviour patterns. The enthalpy metaphor reminds us that for the internal conversation-with-self to be sustained and individual emergence to occur, then we must provide regular stimuli or appropriate metaphorical triggers.

This is of practical significance in the context of the design of learning systems, as it reinforces the need for interest and variety in its presentation, and the crucial need for it to be based around appropriate metaphors as catalysts. Some examples will illustrate the idea:

- In teaching young children how to add or multiply, age will be a factor in determining types of images to use. For very young children, images of soft animals may be appropriate, i.e. one rabbit add two rabbits make three rabbits. For the slightly older, we could approach the teaching of multiplication tables by using images of football teams, e.g. how many players are there in five football teams? six football teams?
- For teaching integration to 18 year-olds, a relevant metaphor for them could be an exercise to find the volume generated by rotating a shallow parabola around the X-axis, in such a way that it forms the shape of a beer mug.
- A secondary school teacher shared an exercise with me for teaching textile design, including needlecraft and sewing, to a group of inner city multiracial 14 year-old youths. A real challenge! She presents the task of using a sewing machine as a driving lesson by using the form of racetrack template, shown below in Figure 3, around which they are challenged to sew. The sewing skills needed are presented as the driving skill of keeping as close possible to the centre of the road. The boys tackle this driving task with great enthusiasm.

The idea of regular triggers provides a supporting rationale for the Open University's approach to design of its learning materials, where typically on every page, interest and activity is incorporated to engage the learner, other than the written word. The item of interest can be a photo, diagram, graph or model etc along with something for the learner to do. This could be to answer a reflective question about that item or link to text, or reinforce what been taught or demonstrated by asking the learner to do a calculation or other exercise. Reinforcement can also be applied by switching to other forms of multi-media such as audio, video or web-based material, to on-line conferences.

The same general considerations for interest and variety apply to the delivery of a lecture. Again, as with conversation-based triggers, there is the distinct possibility of unexpected responses in individuals when exposed to learning materials we have designed, or presentations we give. This may or may not be desirable depending on the context of the learning system. If the learning system is one where there are precise student objectives, then too many unexpected responses will be undesirable. Drawing on the metaphor of the chemical reaction, it may be important to develop specific catalysts for triggers where these can be identified. Evaluation will be necessary to confirm that the catalysts have acted in a specific way and that this is what is required.

It is impossible to remove all variety of individual emergence in programmes of learning, indeed it would be highly undesirable to do so. This is particularly the case in programmes that are seeking to enhance creativity and design in individuals. This is typically also the case in non-mathematical programmes of learning. Catalysts will be required but not those intended to produce a specific response.

Internal thought processes

A sudden unexpected thought can act as an initial trigger, but as has been argued above by itself for most people is normally insufficient for individual emergence. The initial idea is more likely to cause the individual to seek a conversation with others, or seek other external stimuli e.g. undertake research for models. It can also lead to a period of deep reflection, if the individual becomes bonded to the idea or image. Periods of reflection may also be planned as part of a process of thinking about ideas offered by others “Let me think about it and I will get back to you”. Periods of reflection are often planned as part of learning systems e.g. workshops.

As with conversation and other external stimuli, while the opportunity for thinking can be planned, the outcome cannot be determined. Siler [11] has proposed that individuals can be trained to think in more logical and effective ways. His suggested technique involves deliberately contrasting the new issue with a range of metaphor types. In contrast

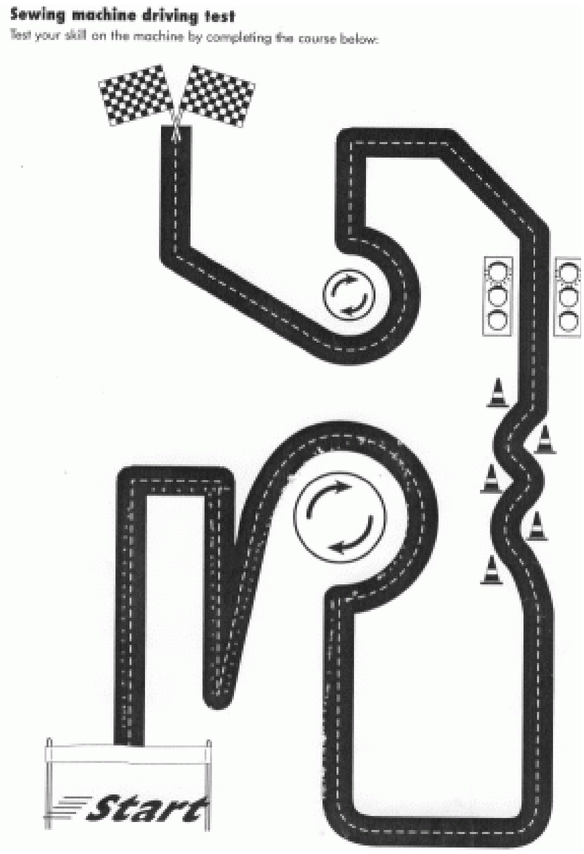

Figure 3: Sewing Machine Driving Test – An appropriate metaphor for the teaching challenge

to the author's inclusive definition of metaphor for the same meaning, he writes "metaphorming. refers to the act of changing something from one state of matter and meaning to another. It begins with transferring new meanings and associations from one object to another" and "Metaphorming involves not just metaphor…but all means of making connections: analogy, figure of speech, symbol, story, pun, story-writing and story telling, scenario making, visualising, hypothesising". Siler refers to making connections, whereas the author prefers to use bonding, as this is consonant with the enthalpy metaphor and the release of internal energy after bonding to sustain the thinking process.

Evaluation of model

Given below is a mapping of the three-source model against the development of this paper and the learning process of the author in writing it. The bracketed numbers in the following description relate to the 3 different categories of source defined above. The initial trigger to participate in the ISPIM 2007 conference learning opportunity was the external stimulus (2) - the call for papers. This was followed by internal reflection (3) – to what extent did the internal metaphor based on 2005 and 2006 conference experiences meet personal needs? This released the energy to begin thinking and writing, drawing on concepts and evidence in external references (2) and on the images and concepts that already existed within self (3) to produce an abstract of the likely paper. After this stage a conversation (1) with a colleague provided further stimuli for reflection following his suggestions to invite conference participants or readers to apply the model themselves. The later stage of the development of the paper was further reading and developing concepts previously explored (2) and then seeking coherence in the ordering and presentation of the ideas, to the author's understanding (3) of the standards required of an academic paper. The final phases involved: reflection on the style of presentation (3) needed at the conference, a conversation with another colleague to seek feedback (1), and a final review of the draft (3). Feedback at the conference (1 and 2) allowed for re-evaluation (3) of the model.

The challenge of submitting to this Journal required further reflection (3), and then necessary adaptation and extension of the paper to try to ensure that it would meet the new audience needs. As a result the author has also undergone yet further individual emergence.

Conclusion

An enthalpy change metaphor provides a useful framework for exploring individual and group emergence. The characteristics of chemical reactions, including activation energy, catalyst, specific catalyst, bonding changes and enthalpy change (energy release) give powerful insights into planning and participation in conversation aimed at sustaining interaction and maximising the potential for creative synergy.

Metaphors also emerge as key driving agents for triggering and sustaining progress towards individual emergence in terms of new learning, understanding, perception and future behaviour change. The model of individual emergence presented here assumes sources of metaphor from (1) conversation (2) other external stimuli (3) internal thought processes. From personal experience and other examples explored, the context is critical in determining which source is most likely to provide the necessary metaphors to initiate an emergence process in an individual, and which source(s) are most powerful in sustaining the emergence. Practical ideas emerge for those who are involved in the design of learning systems and change focussed workshops, namely the need to provide appropriate metaphor as catalysts to engage the learner, to continue to provide metaphors to sustain the learning, and whether specific catalysts are desirable. The paper has highlighted some of the difficulties associated with individual emergence; we can plan programmes for learners but we must always be alert to the possibility that their emergence will not be as we expect. We recognise that culture, values, current knowledge, and interests represent high activation energy levels, which can act against an individual engaging in a learning/change process; the challenge is to find context relevant catalysts to reduce the activation energy level.

This paper is offered as a guide to consider the issue of individual emergence. These ideas have come from the discipline of social system design,

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but it is hoped that readers interested in learning design can apply the ideas to suit needs in their own context.

Readers are invited to reflect on what represented the key sources of their emergence during the reading of this paper, and to contact the author with any reflections.

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Practitioner's Section

Chemical Plant Engineering Projects – Customers Around the World Prefer Cutting-edge Technology "Made in Germany"

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Abstract: The German large industrial plant manufacturing industry is currently going through an extraordinary boom phase. Bookings by members of the Large Industrial Plant Manufacturer´s Group (AGAB) at the German Engineering Federation (VDMA) set a new record in 2006 for the second straight year. This paper highlights the underlying developments in the sale of new plants, putting special emphasis on the regional and industrial particularities and closes with an outlook for 2007 and 2008.

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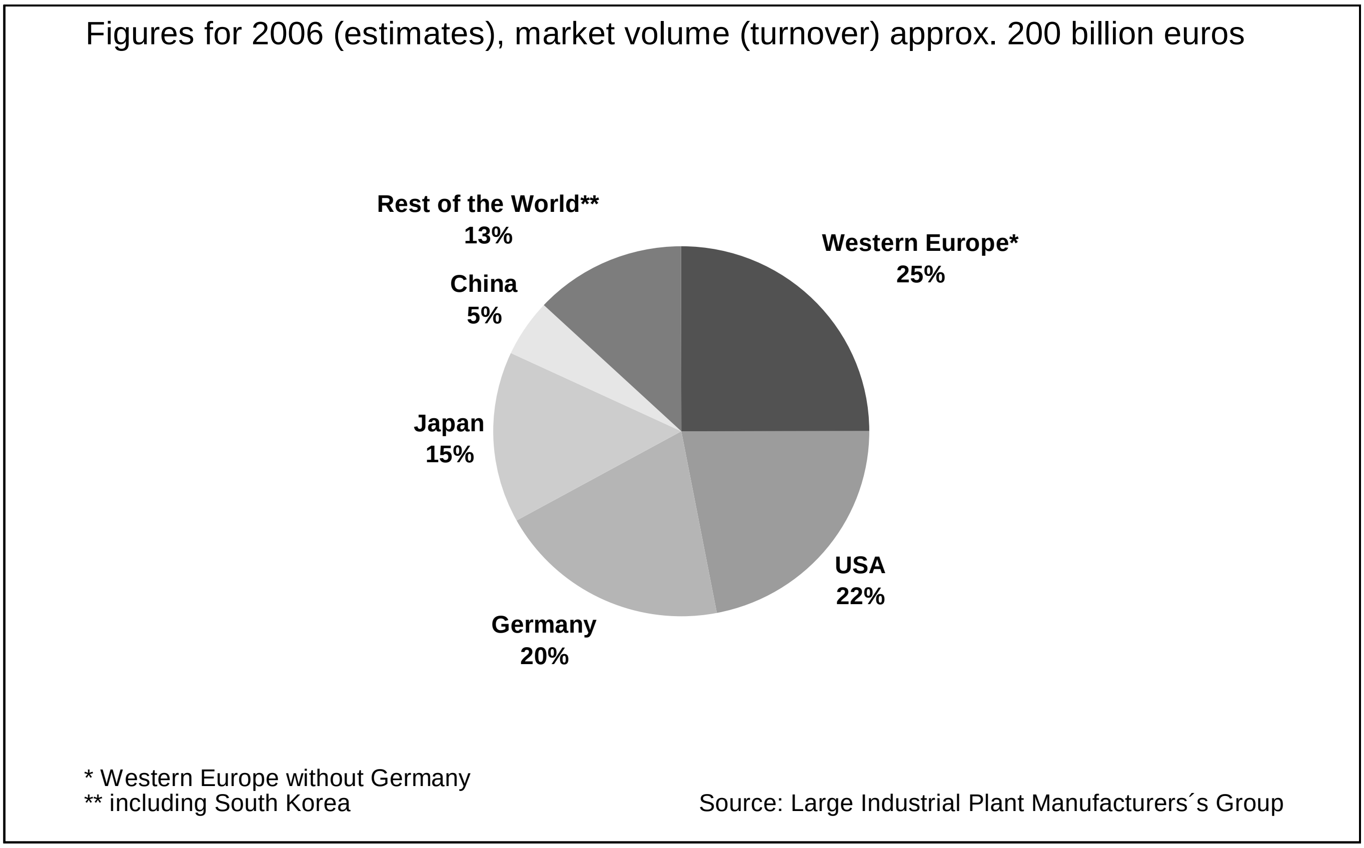
Introduction

The German large industrial plant manufacturing industry is currently going through an extraordinary boom phase. Bookings by members of the Large Industrial Plant Manufacturer´s Group (AGAB) at the German Engineering Federation (VDMA) set a new record in 2006 for the second straight year. Orders valued at €26.3 billion represented a 9% increase compared to the previous record of €24.1 billion which was set in 2005. Bookings in 2006 were actually about 50% higher than the average for the ten year period between 1997 and 2006 (€17.6 billion). The industry has now been in an expansion phase for four consecutive years. The last time the industry experienced similar growth was during the boom at the beginning of the 1990s in the wake of German reunification. Growth in the German large industrial plant manufacturing industry has also been very impressive in the international context. Market share increased to around 20%, placing German engineering firms among the world's elite corporations from Western Europe, the US and Japan which construct industrial production facilities. Using bookings as the yardstick, power stations, steel plants and rolling mills were the most important market segments. Last year, chemical plants were the third most popular type of project. Bookings in this segment were up by 10% to a record of €2.7 billion (€2.4 billion in 2005). Orders for the year were an impressive 42% higher than the long-term average of €1.9 billion between 1997 and 2006.

The German chemical plant engineering industry can design and build a wide range of facilities for a variety of different applications. The list of examples includes fertilizer plants, refineries, synthetic fiber and polymer production plants, electrolysis plants and gas or coal liquefaction facilities. The value of individual orders often exceeds €100 million and can even be as high as a billion euros.

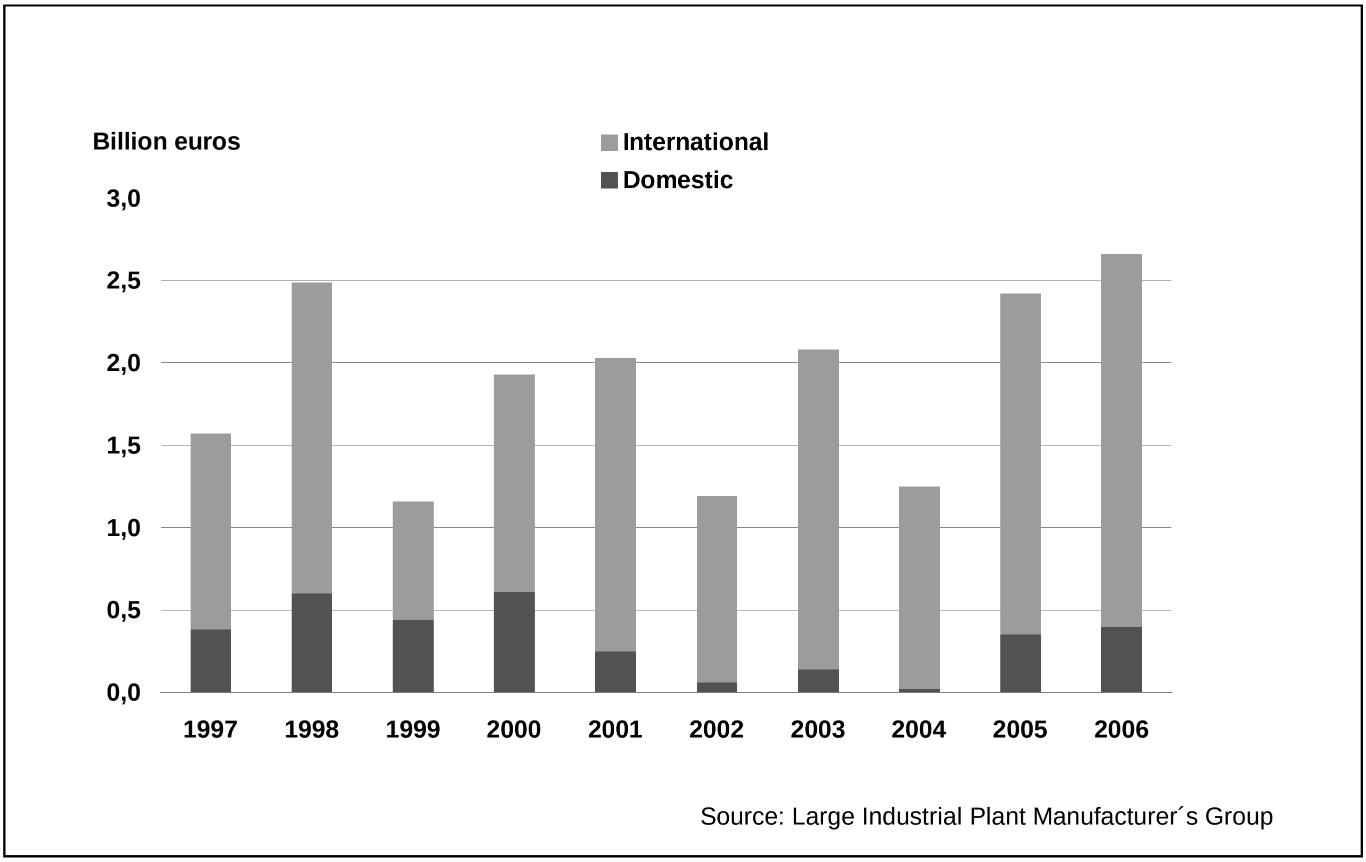


Figures for 2006 (estimates), market volume (turnover) approx. 200 billion euros

* Western Europe without Germany
** including South Korea

Source: Large Industrial Plant Manufacturers´s Group

Figure 1: World Market share – large industrial projects – breakdown by country and region



Source: Large Industrial Plant Manufacturer´s Group

Figure 2: Incoming orders for chemical plants 1997 - 2006

Growth in the domestic market

Following years of investment restraint, domestic demand for chemical production facilities began to recover at the end of 2005. This trend continued into 2006 on the back of a good investment climate in the chemical industry. Domestic orders acquired by working group members were up by 14% to €395 million compared to €347 million in 2005. The last time bookings exceeded that level was in 2000 when total orders amounted to €600 million. Large-scale modernization projects to increase the efficiency or expand the capacity of existing plants combined with new construction (e.g. in the petrochemical industry) have contributed to the upswing.

Region	**Inorganic chemistry**		**Organic chemistry**		**Total**	
	2006	Change compared to 2005 in %	2006	Change compared to 2005 in %	2006	Change compared to 2005 in %
Domestic	166	118	229	-16	395	14
International	241	-40	2,025	21	2,266	9
Total	407	-15	2,254	16	2,661	10

Table 1: Incoming orders – German chemical plants projects (2006 in million euros)

Germany: The end of the biodiesel boom?

On the other hand, the crest of the biodiesel wave in Germany, at least as far as new production facility construction is concerned, seems to have passed. Existing annual production capacity of around four million tons of biodiesel, higher taxes on this alternative fuel and a shortage of additional land for rapeseed cultivation (which is the basis of domestic biodiesel production) lead experts to believe that demand for new plant construction will be weak in the medium term, at least as long as only domestic feedstock is used. It came as no surprise that orders in this segment were only a modest €14 million in the reporting period compared to a record of €180 million in 2005. New production facilities for biodiesel and bioethanol will be built primarily in the EU, the US, China and Brazil in the near future.

International orders at a record high

Demand in the chemical engineering sector was driven primarily by international orders. The export quota was 85% (2006: 86%), which was significantly above the overall average for the large industrial plant manufacturing industry (77%). International orders reached a record of €2.3 billion, a 9% increase compared to 2005 (€2.1 billion). The main markets were the Caribbean, North Africa, the Middle East and the former Soviet Union. Large sums were invested in these regions in gas and oil processing facilities. Members of the working group also reported bookings from countries which traditionally have a strong chemical industry or a large local increase in consumption, for example China, Poland and Malaysia.

Latin America: Large investment in Trinidad and Tobago

In the wake of the economic crisis which shook Latin America in 2001, business activity slowed down significantly in the region. The effects of these events on the German plant engineering industry were reflected in lower bookings. Order volumes between 2003 and 2005 were down 35% compared to the long-term average. As the business recovery in Latin America has gathered pace, investment activity has increased again, and this has been most noticeable in the chemical plant engineering sector. The largest market was Trinidad and Tobago. Construction of a huge petrochemical factory accounts for the lion's share of the orders valued at €850 million which were received from the island nation. Ammonia, liquid fertilizer and melamine can be produced at the new complex. Natural gas, which is extracted off the coast of Trinidad and Tobago and processed at the plant, is used as the feedstock for these products.

Medium-term sales prospects for the German chemical plant engineering sector are encouraging in Mexico and other Central American countries, because plans are in place for several large petrochemical projects and new refineries. The current biofuel boom in Brazil has driven demand for production facilities in recent years. There are plans to build 75 bioethanol plants between now and 2013 at a total cost of more than ten billion euros. Venezuela has large oil reserves, making it an attractive market for the chemical plant engineering sector. However, increased government control of the oil and energy market is having a negative effect on the domestic investment climate.

A slowdown in investments in the Middle East – Business potential in North Africa

The Middle East remains a key market for the German chemical plant engineering industry, despite the fact that bookings dropped significantly from €1.2 billion in 2005 to €345 million in 2006. However, this is only a snapshot view. The sustained trend towards increased value-add and the resulting planned investment in petrochemical plants and refineries would seem to indicate that demand will increase again in the near future. The fact that orders worth more than €700 million from the region were received from January to June 2007 (which is double the total for all of 2006) is a good indication that this assumption is well founded. Saudi Arabia was the most important customer for the German chemical plant manufacturing sector in the reporting period. Bookings from the kingdom stood at €266 million, and additional orders worth

	Inorganic chemistry		Organic chemistry		Total	
Region	2006	2005	2006	2005	2006	2005
Middle East	2	346	352	862	354	1,210
Asian-Pacific Region	40	23	300	230	340	253
Eastern Europe and CIS	152	2	183	38	335	40
Industrialized Nations	26	21	69	311	95	332
Rest of the World	21	7	1,121	233	1,142	240
Total	241	399	2,025	1,674	2,266	2,073

Table 2: International incoming orders by country group (2006 and 2005 in million euros)

€60 million were received from Iran. Overall, three of the ten largest national markets were in the Middle East during the past five years (see table 3).

The countries of North Africa, particularly Egypt and Algeria, are actively pursuing the goal of increasing local value-add. They are strengthening their economic base by converting oil and natural gas into high-value chemical and petrochemical products. The Egyptian fertilizer industry has recently been making massive investments to expand capacity, and German chemical plant engineering companies have received sustained benefit from these efforts. Orders valued at €228 million were received from Egypt last year (compared to €82 million in 2005). However, hopes for more orders from Libya following the improvement in political relations have not yet been fulfilled. A difficult restructuring process has just gotten underway at the large state-owned companies, and this has noticeably delayed the planned modernization of the refinery sector.

China still the leading market in Asia

China remains the major export market for German plant engineering firms in general, and this is particularly true for the chemical sector. German companies booked orders worth €166 million (2005: €183 million) from the People's Republic. The requirement for above-average local content, an extremely tough competitive environment and insufficient protection of intellectual property rights are characteristic features of the Chinese market. As domestic demand continues to rise in China, the level of investment will increase across the board in the chemical industry, and in the petrochemical sector in particular. The country has large coal reserves, and there is significant interest in exploiting this resource as a raw material for the petrochemical industry. Initial orders have already been placed with German companies.

The national economies are growing very rapidly in Southeast and East Asia, and as a result the chemical industry is gaining a foothold or expanding in many countries in the region. In addition to China, Thailand and Malaysia are major markets for the plant engineering industry. A biodiesel industry using palm oil as the raw material is currently being established in these two Southeast Asian nations. The goal is to reduce dependency on imports of conventional fuel. Plants are also being built for the production of hydrogen and fatty alcohols which are used to make cosmetics and cleansers. Vietnam, South Korea and Taiwan are further important markets for the German plant engineering industry.

The Indian economy is growing at a remarkable rate. Political stability and a well functioning financial market provide a favorable environment for the manufacturing sector. Investments in infrastructure and expansion of the country's chemical industry have accelerated in recent years. Production of polymers, fine and special chemicals has grown at disproportionate rates. Despite intense international competition, German chemical plant engineering firms have good opportunities to modernize existing plants and construct new production facilities. India is expected to remain one of the world's most attractive growth markets.

Strong growth in Eastern Europe and CIS countries – The market in the industrialized countries remains sluggish

German plant engineering companies booked orders worth €335 million from Eastern Europe and the CIS countries in 2006, which is a five-year high. Orders valued at an impressive €137 million were received from Poland (compared to €10 million in 2005). This mainly reflects investment in the petroleum processing industry. The growth of the Russian and Ukrainian economies, particularly the chemical sector, provided the stimulus behind several large contracts for electrolysis and PVC plants. Increased project activity is also evident in other countries in Eastern Europe and Central Asia.

No significant orders were received from Western Europe and North America last year. Working group members only received contracts for a few small expansion or revamp projects. However, because the European chemical industry is running at full capacity, there should be demand for new orders including new turnkey projects in the medium term.

Despite sluggish economic performance, the North American market offers some attractive opportunities in the chemical plant engineering sector. The US market for coal liquefaction facilities is expected to show sustained growth, because the country plans to increase investment in this type of plant as part of its energy autonomy program. German chemical plant engineering firms have the right technology and should be well positioned to take advantage of increasing demand in this segment. The same applies to the biodiesel industry. Expansion of oil sand production in Canada will require significant new investment in large-scale production facilities (for example to extract heavy oil). This should also provide significant opportunities to the German companies.

Air separation and gas liquefaction

Air separation and gas liquefaction facilities are not included in the above mentioned bookings for the chemical plant engineering industry. However, it is an important market segment for the process industry, and it is worth mentioning. Orders received by suppliers of air separation and gas liquefaction systems increased last year by 71% to

Country	Orders	**Types of plants ordered** (examples)
1. Trinidad & Tobago	1,691	Facilities to produce methanol, ammonia and melamine
2. Saudi Arabia	1,113	Facilities to produce ethylene, propylene, fertilizer and olefins
3. Egypt	1,000	Fertilizer plants
4. Iran	983	Ethylene production facilities
5. P.R. China	613	Coal liquefaction and gasification facilities, coke plants
6. Poland	350	Electrolysis plants, production of aromatics
7. Oman	330	Fertilizer plant, methanol production facility
8. Belgium	321	Electrolysis plant, ethylene dichloride production facility (EDC)
9. Turkmenistan	249	Fertilizer plant
10. Libya	237	Petrochemical production facilities

Table 3: International bookings in major markets 2002-2006

a record €1.7 billion (2005: €1 billion). Strong demand for air separation facilities in 2006 was driven by applications such as the production of fuels from natural gas (gas to liquids or GtL) which has now become competitive due to the high cost of raw materials. Strong economic performance in the industrial gas sector is also stimulating the market. Demand for GtL facilities comes primarily from Northern Europe and the Middle East where liquefaction of natural gas is an economically attractive alternative to conventional transport of gas through pipelines.

Production capacity continues to increase

Customers have been asking engineering firms to build larger and more efficient chemical plants in recent years. Average output volumes of commodities (e.g. ethanol, methanol and ammonia) have increased by a factor of 2 – 5 during the past ten years (see table 4). It is still possible to manage even larger material and energy flows, but the production, transportation and handling of very large, heavy subsystems are becoming increasingly difficult. Furthermore, as more capacity comes online, concentration on a few mega projects represents a financial risk to the plant owners.

For the time being, the popularity of mega commodity plants is likely to continue. Increasing demand for the chemicals which are produced at those plants, particularly from customers in China and India, will ensure that global capacity does not reach the saturation point. Relatively low investment per unit of output at these large-scale plants makes them significantly more profitable for their owners. For German companies which have established a solid position in the chemical plant engineering market, this trend is definitely good news, because it makes things more difficult for new entrants to the market. Engineering firms that cannot produce references from large, risky projects cannot obtain credit insurance, and for that reason alone they will not be invited to submit bids for these contracts.

Over the long term, increases in productivity and output capacity will be achieved though advances in process technology rather than through economies of scale. With this in mind, plant engineering firms are investing in the further development of nano, microprocess and microsystem technology. However, these technologies are still in their infancy, and it will take another few years before they are ready for wide-scale deployment.

New raw materials for the chemical industry

Petroleum has been the dominant raw material in the chemical industry for many years. However, rising oil prices in recent years have accelerated the search for alternatives. Natural gas, coal and biomass are potential substitutes. Which of these raw materials will be used on a larger scale in the chemical industry depends among other things on the availability and relative price of the raw

Plant Type	**Capacity**		
	~ 2000	**~ 2005**	**~ 2010**
- Ammonia urea plant	2,000 t/day	3,500 t/day	4,500 t/day
- Biodiesel plant	50,000 t/year	300,000 t/year	600,000 t/year
- Ethylene plant	600,000 t/year	1.5 million t/year	no information
- GTL plant	35,000 b/day	35,000 b/day	70,000 b/day
- Methanol plant	2,000 t/day	5,000 t/day	10,000 t/day

Table 4: Capacity of the largest process manufacturing plants (in metric tons per day (t/day), metric tons per year (t/year) or barrels per day (b/day)

materials.

In the short term, oil and above all natural gas will be important basic materials in the chemical industry. Coal should become more significant in the medium term. Projects which are focused on the production of chemicals or fuel directly from coal are underway or are in the planning stages in countries which have large coal reserves such as China, the US and Australia. However, high investment costs and problems surrounding carbon dioxide emissions are impeding the widespread use of coal-based techniques.

The use of biomass will increase in the long term assuming that prices for fossil-based raw materials do not fall significantly below current levels (and that appears to be a safe assumption). In the initial stages, improved conversion technology should make renewable raw materials economically attractive for selected chemical products. If the price relationship between fossil and sustainable raw materials continues to change significantly, then biomass could become a more important factor in the production of basic chemicals.

The members of the working group have in-depth expertise in the types of feedstock mentioned above. The companies are well-positioned to take advantage of future growth in the chemical industry regardless of whether oil, gas, coal or biomass is used as the raw material.

China – A new competitor in the international (chemical) plant engineering market

Companies based in Western Europe and North America dominated the plant engineering business until around 1960. Japanese plant engineering firms joined the elite group in the mid 1960s, and Korean companies became serious competitors in the early 1990s. Another Far East competitor entered the scene at the beginning of the current decade, namely the Chinese plant engineering industry.

In recent years, Chinese plant manufacturing companies have caught up very quickly and with a great deal of success. Their market share was negligible just a few years ago, but they have now captured market share in the three to five percent range outside the People’s Republic, and the figure is rising (see figure 1). Companies such as SINOMA (cement plants) and CTIEI (synthetic fiber plants) are already important players in their market segments.

Chinese companies have also become serious competitors in the chemical plant engineering market. Following initial successes in the South and Southeast Asian region early in this decade, Chinese engineering firms such as SINOPEC have been able to acquire more demanding customers in the Middle East.

Established market players have taken wide-ranging measures to counteract stiffer competition from the Chinese. In response to increasing price pressures in particular, German chemical plant engineering firms have set up or expanded their own local engineering, administrative and production capacity at sites in Eastern Europe, India and China.

There is no way of predicting where the Chinese plant engineering industry will be ten or fifteen years from now. In the short term, increased competition appears to be virtually unavoidable. German engineering firms will have to make every effort to maintain their technological and methodological advantage while keeping costs under control. They must also ensure that customers understand the economic advantages of German solutions. A holistic cost/benefit analysis which includes the ongoing operation phase reveals that engineering and hardware costs account for only a small percentage of total cost. The quality of the supplies, performance to schedule, availability, energy efficiency, plant productivity and the cost of the raw materials used in the process are far more important.

These factors in turn have a major impact on the financing terms and project ROI. A lifecycle analysis shows that initial construction only accounts for 10% of total cost, whereas raw materials account for 35%. From the holistic point of view, German engineering firms will still maintain a crucial advantage in the medium term over their Far Eastern competitors.

Industry strengths

In-depth expertise in project and risk management methodologies coupled with technology leadership and solid financing are the real strengths of the German chemical plant engineering industry. However, companies must continue to develop their expertise to ensure that they are able to cope as projects become larger and larger. The companies also have impressive world-wide procurement expertise, and they continue to expand their supply base without compromising their quality standards. They also fully exploit the advantages of global project management. After all, the international competitiveness of the German plant engineering industry is based on world-wide presence, innovation, excellent quality, performance to schedule and the ability to supply solutions which offer low lifecycle costs. In order to maintain their leadership role in the face of tough competition from companies in Europe, the US and Asia, German companies will have to continually develop their expertise.

Positive outlook for 2007 and 2008

The industry expects that demand will remain strong in 2007 and that orders will at least equal the good results of the previous year (€2.7 billion). Given the strong business performance of the chemical industry, the three billion Euro threshold could be reached this year for the first time. The long-term outlook for the chemical plant engineering industry is also excellent. The optimistic forecast is based on factors such as the continuing need for high investment in the rapidly growing economies in China and India, a recovery in the European chemical industry and the ample funds which are available for investment in countries that have large raw material reserves in the Persian Gulf region, North Africa, South America and the CIS. A continued deterioration in the Euro/Dollar exchange rate could dampen the outlook in key customer markets in the Middle East. However, the positives outweigh the negatives. The German chemical engineering companies are therefore optimistic that 2007 and 2008 will be good years for the industry.

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