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Skill needs in emerging technologies: nanotechnology

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Foreword

The fast development of nanotechnology is often defined as a fundamental revolution in technology compared to discovery of antibiotics, television, nuclear weapons, or computer technologies. The workshop discussed the current situation and the development potential of this technology and new technologies as such. The aim was to focus on approaches and first results to identify future skill requirements and new emerging occupations in the EU. Nanotechnology is a cross-sectoral and highly interdisciplinary field and its development brings along several completely new tasks, and even jobs and occupations whose requirements have to be identified and transferred into education and training without delay. The workshop attempted to tackle some of the concerns in the area of skill needs.

The workshop Emerging technologies: new skill needs in the field of nanotechnology was organised by Cedefop's network on early identification of skill needs, Skillsnet, jointly with the Fraunhofer Institute for Industrial Engineering (Fraunhofer IAO), the German Federal Ministry of Education and Research (BMBF), and the Institute of Structural Policies and Economic Development (isw) in Stuttgart, Germany in July 2005. Participants and speakers from 13 countries came to discuss and share the knowledge and experience concerning new skill needs in the field of nanotechnology from the perspective of their backgrounds: research, business, education and training. The present publication results from proceedings of the workshop presentations and discussions.

Part I focuses on identification of trends and skill needs in nanotechnology in Europe. Three contributions provide analytical overview of trends and developments in various fields of nanotechnology and their related skill needs. Part II presents two country examples. The developments, skill and training needs in the field of nanotechnology are presented from the Czech and German perspective. Part III reviews different networking activities and initiatives related to emerging technologies and nanotechnology in particular. Part IV provides summaries and conclusions from the working groups discussions on nanotechnology and its effects on skill needs and occupational profiles and on skill shortages and skill gaps in emerging technologies. The final chapter is based on presentations and discussions during the whole workshop and summarises the event and its conclusions.

The workshop gave a clear message that nanotechnology is still very much under development. It has a multidisciplinary character and, therefore, it is difficult to plan future skill needs especially at the intermediate level. As far as specialists and scientists with tertiary education are concerned, a clear message is that Europe has already now a shortage of specialists, and this shortage is expected to increase in the future. There is a need for monitoring intermediate skill needs and one could learn from the experience of other new and emerging technologies. As soon as nanotechnology will go into a mass production, the shortage of skills in the intermediary level of occupations will become obvious. The debate on ethical and legal questions also brought about the conclusion that general risks and the social impact of nanotechnology are difficult to predict and more research in this field is necessary.

Given the evident interest from the members of the network, Skillsnet intends to continue the debate about new technologies and related skill needs in the future, organising workshops and supporting analytical activities in early identification of skill needs.

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Trends and applications in nanotechnology and their impact on future skill needs

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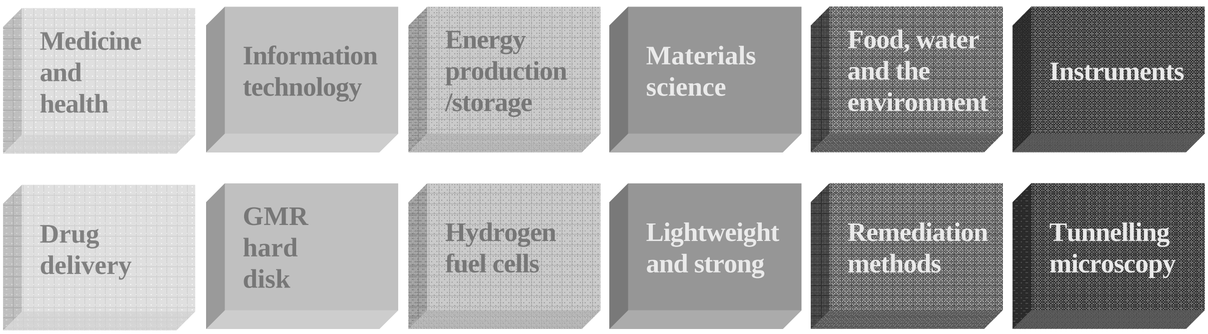
1. Introduction to nanotechnology

Nanotechnology is an interdisciplinary technology of manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with control geometry and at least one component below 100 nm (nanometer) including advanced equipment that allow controlled fabrication, measurement and visualisation with high resolution. Nanotechnology can work in the top-down approach (which means reducing the size of the smallest structures to the nanoscale) or the bottom-up approach (which involves manipulating individual atoms and molecules into nanostructures and more closely integrates chemistry or biology with microelectronics). Very small (nm) dimensions make available and enhance new physical (electrical, optical, magnetic, mechanical, thermal), chemical, and biological properties which cannot be achieved above the critical dimensions (> 100 nm). They designate nanotechnology an unprecedented era of innovation across multiple disciplines and diverse applications in information technology and communications, materials science, medicine, biotechnology, genomics, manufacturing, renewable energy and environmental protection. Nanotechnology opens up new market opportunities and is considered as the key technology of the 21st century.

Figure 1: Nanotechnology and examples of its applications



Analysts estimate that the market for products based on nanotechnology will rise to hundreds of billion EUR by 2010 and exceed one trillion later. The main industrial sectors exploiting nanotechnology products comprise information and communication sector, medical sector particularly for novel diagnostics and targeted therapy, automotive industry for more safe, comfortable, clean and economic drive, instrumentation technology for production of more precise manipulation and analytical tools with higher resolution in reasonable cost.

2. Impact on skill needs

Strong society requirements are a driving force of the nanotechnology development. Increasing miniaturisation, convergence of functions and systems including their intelligence require more advanced technology with more integration and interdisciplinarity. The establishment of complex research environment and infrastructure capable to serve the visionary and industry relevant activities is a necessity. High technology is driven by highly qualified experts and strong demand on education in the interdisciplinary field of nanotechnology is a logical consequence of this process. The estimations summarise that there is a need for about half million new experts in the nanotechnology field in Europe within the next 10 years.

The corresponding curricula should be based on good theoretical background provided by mathematics and physics together with chemistry (surface chemistry, organic synthesis), biology (biophysics) integrated with applied sciences particularly material science, microelectronics technology, instrumentation technique. Modelling and simulation should be used as an effective tool for any design and interpretation of experimental results. The school learners/graduates should have personal ability for critical analysis and thinking, innovative design, and interdisciplinary integration. They should addressed societal and ethical issues, problems with invaded privacy and consider environmental problems. For global companies the workers should be specialised, able to communicate in international teams, prepared for mobility and travelling while in small and medium companies (SMEs) the emphasis will be on their multidisciplinarity and diversity, leadership, decision-making, and entrepreneurship skills. The graduates should considerably improve the ability to generate, manage and exploit of knowledge, immediate technology transfer with particular effort to capitalise of knowledge by industry.

It is clear that nanotechnology has very difficult multidisciplinary curricula which establishment requires intensive collaboration between departments, faculties, universities to gain critical mass and accessibility to best R&D laboratories for practical training through research. Coordination of fragmented teaching (graduate and postgraduate) activities at national and European level and exchange of best practice is another important feature of the integration process.

The nanotechnology is very dynamic innovative technology with new achievements, materials, processes, devices, test procedures, tools and there is a need for lifelong learning and training. Also vocational education and training in a specific nanotechnology fields (special processes, analysis, testing, M&S) for highly qualified technical personal should be properly addressed by educational institutions.

The inadequate interest of young generation in technology oriented studies in general is a potential risk which can result in a lack of highly qualified workers in nanotechnology field which is considered even more difficult and complex study. To overcome this problem and attract more and talented students to the field increasing awareness of nanotechnology, demonstration of its benefits to all citizens, motivation of students starting very early from basic and secondary schools is very important task of the knowledge-based society.

Despite the fact that the new properties of nanoparticles and nanodevices in general improves the quality of our life, the potential risks, for example human and environmental considerations (gene engineering, new dangerous materials), should be analysed and openly communicated to the wide society in an appropriate manner.

To share the extremely expensive investment, the intensive interaction and collaboration at national and international level and new scheme for public-private partnership and funding are necessary to ensure the EU competitiveness in nanotechnology which is considered as EU priority research.

Identification of skill needs in nanotechnology: overview based on the secondary analysis°([1])

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1. Introduction

The nanotechnology sector is set to play a key role worldwide in the 21st century. Nanotechnology is trend-setting in nearly all industrial areas and is advanced through an ever growing number of discoveries.

In the course of the secondary analysis *Identification of skill needs in the nanotechnology sector*, by order of Cedefop, latest selective research, development tendencies and trends in the different fields of nanotechnology and their related skill needs are expounded. National and international activities and institutions, especially across Europe, the US and Asia are described. Institutions for early identification of skill needs in the field of nanotechnology are introduced across Europe. On the basis of fields of research, tendencies of development, technologies, enterprises and fields of work related to nanotechnology at international level and in different countries related skill needs are represented as well as basic, all-embracing and special occupational and skill needs related to nanotechnology.

The research objectives for the secondary analysis were the following:

(a) to represent the nature of nanotechnology, fields and sectors of its application and its implementation, particularly in Europe;
(b) to review estimates and forecasts of significance and scientific-technological developments of nanotechnology in various fields;
(c) to investigate the future demand on the nanotechnology labour market;
(d) to identify major sources and institutions involved in identification of future skill needs for the nanotechnology sector;
(e) to make an overview of research results on specific and general/basic skills and particularly innovative skills required and new occupations emerging in the context of nanotechnology;
(f) to propose ways of implementation and verifying Europe-wide innovative qualification and training measures in the nanotechnology sector.

2. Methodological approach

Two methodological instruments had been used, the secondary analysis and the systematisation matrix.

The secondary analysis has focused on available research on qualification demand in the sector of nanotechnology. It generated a compilation of research results as well as an overview of actual skill needs. Sources for the secondary analysis were the internet, various data bases, library and isw project on early identification of trend-setting skills in the nanotechnology sector. Results database consist of a broad information material like project documentations, different publications, and statistics, etc.

([1]) Abicht et al., 2006.

During the project *Ermittlung von Trendqualifikationen im Bereich der Nanotechnologie* (Identification of trend-setting qualifications in the nanotechnology sector) ([2]) the systematisation matrix was developed on the basis of principles of the general technology. With the aim of creating an instrument that allows for examining the different manifestations of nanotechnology, as there are technical systems, processes, principles and effects, systematically towards trend-setting qualifications.

3. Results

Nanotechnology means the production, examination and application of structures, molecular material and inner border areas and surfaces with at least one critical dimension or production tolerance under 100 nm (Bachmann, 1998). One nanometer is one millionth of a millimetre. Due to the nanoscale and the typical quantum mechanical phenomena prevalent there, new functions and properties are added which allow the improvement or development of new products and application possibilities.

Nanotechnology is a cross sectional technology that has besides its fields much range of application, as shown in Figure 1. This reveal, that the development of almost every industrial sector is influenced by the development of nanotechnology.

Figure 1: Nanotechnology sectors

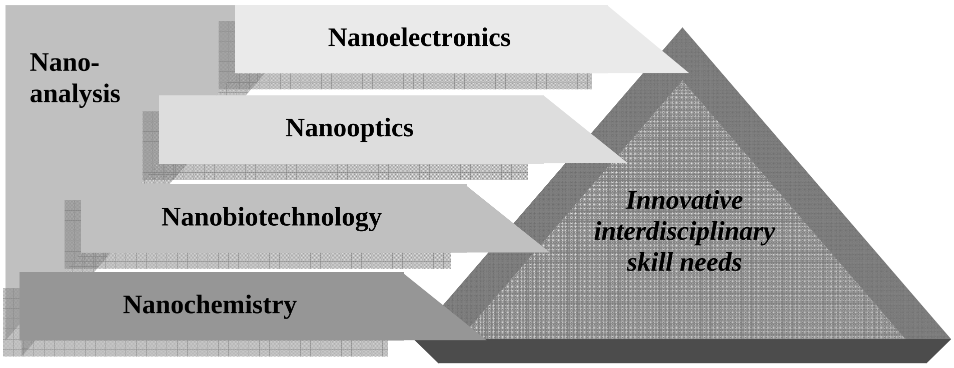

Table 1: Nanotechnology sectors and their application fields

	Nano-analyses	Nanobiotechnology/ Nanomedicine	Nanomaterials/ Nanochemistry	Nanoelectronics /Nanooptics
Energy- and environmental technology, technology of measurement	❍❍	❍	❍	❍
Life sciences, medical technology, pharmaceutics, cosmetic procedures	❍	❍❍❍	❍	❍
Chemical industry, textile industry, food stuff industry	❍	❍	❍❍❍	❍❍❍
Information- and communications technologies	❍		❍❍	❍❍
Automobile industry			❍❍	❍

Short descriptions of the different nanotechnology sectors are given below:

([2]) Further information on the project are to be found on the internet: www.isw-institut.de/nano [cited 4.9.2007].

(a) nanoanalysis: refers to special techniques for determining the atomic structures of materials. It is a cross sectional science which supplies analytic methods and means for recording basic phenomena and for characterising products, and furthermore causes an analytical quality assurance by making a contribution to national and international standardisation. Nanoanalytical techniques offer many possibilities to make scientific information available to the fields of physics, chemistry, biology, materials science and engineering on nanometer scale. Steady miniaturisation absolutely requires understanding in and control of processes on the nanoscale;

(b) nanobiotechnolgy/nanomedical technology: this field of nanotechnology combines technological processes with the knowledge of biosystems at nano level. Two principal strategies can be used. On the one hand the bio ⇨ nano strategy, which uses scientific findings of biological systems as pattern for developing technological systems, in the sense of nanobionic. On the other hand the nano ⇨ bio strategy, that makes nanotechnological processes do affect experience with biosystems persistently. Furthermore nanobiotechnology offers a high innovation potential for the food industry, agriculture and ecology. Important natural scientific fields linked with nanobiotechnology are for example molecular biology, genetics, colloid chemistry, biochemistry, surface physics, and quantum mechanics. From the technical side, engineering is significant to the development and implementation of nanobiotechnological products or systems and (its) processes/methods it is based on. Especially the medical and pharmaceutical branches of diagnostics and therapeutics with their different fields of research and development occupy an important part of nanobiotechnology;

(c) nanomaterials/nanochemistry: nanochemistry deals with creating and manipulating nanoactive chemical systems. Supramolecular functional systems are the basic principles for forming new materials. Nanochemistry – which is internationally not standardised – means chemical changes in systems, which work exclusively on the nanoscale. Nanochemistry specifically includes functional supramolecular systems, for example transport of active agents, systems that can be switched or controlled, systems with regulable characteristics, functional coatings, and the formation processes of nanoparticles (particles, colloids, fluids, nanotube) (Bachmann, 2002);

(d) nanoelectronics: is not subject to a strict definition because the transition from microelectronics to nanoelectronics is fluid. At this time microelectronics deals in the realm up to 90 nm. Integrate circuits (significant) below the 100 nanometerscale are called nanoelectronics. It is reckoned on a further miniaturisation (top-down approach) down to 23 nm (10-9 m) within the next decade. The optical lithography reaches its limits for physical laws (wavelength), so that a change in technology can be expected in the near future;

(e) nanooptics: include the research, development and production of optical components, structures and systems on the nanometer scale. Nanooptics deals with several branches like ultraprecision optics that manufactures nanometer precise lenses and lens systems used in appliance optics and medical optics. Laser technology, that is used for optoelectronical components in the information an communication technology, is a further important branch. In optics or photonics nanotechnological aspects are important at different places. Phontonics deals with technologies for production and application of light and other radiant energies, which are based upon photons. The range of application of photonics is many and diverse; it extends over energy production, detectors, telecommunications and informatics.

In these different sectors of nanotechnology there are diverse applications. New hydrogen-energetic store by means of carbon nanotube and the use of environment protective technologies (nano filters, sewage treatment) are only some of them. The application of new technologies of measurement and analysis expedite nanotechnological developments.

4. Effects on skill needs

With the implementation of new products and services the demand on well trained staff in different industrial fields of work will increase. In the following fields of work new demands referring to nanotechnology begin to emerge. That concerns the fields of research and development, production and manufacture, quality assurance, documentation as well as marketing and distribution that are briefly described below.

4.1. Research and development

Currently R&D is the most dominant field of work in nanotechnology and nanoscale science respectively. In general, that is why it is a relatively new field of research. It is also because, new nanoanalytical methods such as the scanning tunnelling microscope, that makes it even possible to manipulate single atoms, are available only just for a short time. For this invention Gerd Binning and Heinrich Rohrer have been awarded the Nobel Prize in 1986. By this nanoanalysis, chemical processes, physical effects, biological principles and materials of all kind can be examined down to atom-scale range of size. This allows for specific research and development in the nanotechnology sector.

4.2. Production and manufacture

Nanotechnological intermediate products, products and final products are already produced in several branches, such as nanoparticles or nanosurface coatings. Further products are expected with up-and-coming tendency. Here automation is increasing and process control becomes more and more complex as well as meaningful.

4.3. Q uality assurance

Due to the fact that nanotechnology is a new field of development, only little quality standards exist so far. Nevertheless, working with nanoscale objects requires special working conditions, for example clean rooms, that demand a great deal of meeting quality standards. This includes dealing with special protective clothing, materials and substances.

4.4. Documentation

Dealing with special nanotechnological data partly demands for specific corresponding data processing, for example information management systems in laboratory or the use of data bank with nanotechnological parameters. Besides literature research also online research into different nanotechnological aspects can be counted to the area of responsibility on documentation.

4.5. Marketing and distribution

Nanotechnological products and service are very explanation-intensive. The combination of nanotechnological, customer-related knowledge and commercial competences are more and more demanded for.

Education and training in nanotechnology at the level of intermediate qualification receives little attention so far, even though there do exist new job demands in this field of education. In Germany the project Identification of trend-setting qualifications in the nanotechnology sector investigated into new demands for jobs and qualification in the nanotechnology sector and as a result so-called qualification profiles has been outlined (Table 1).

Table 1: Overview of qualification profiles for nanotechnology

	Cluster-specific qualification profiles	**Cluster-embracing qualification profiles**
Nanochemistry/materials /nanoanalysis	(1) nanochemical laboratory assistant (2) nanoassistent (3) materials scientific-laboratory assistant	(15) nanoanalyst
Nanobiotechnology/ nanoanalysis	(4) specialist in nanobiotechnology research (5) specialist for biohybrid technologies (6) specialist for quality assurance (7) specialist for documentations on nanobiotechnology (8) product adviser for nanobiotechnology applications	(16) specialist for nanosurface treatment (17) specialist for documentations on nanotechnology
Nanooptics/ nanoanalysis	(9) specialist for ultra-fine optics (10) specialist for photonics/laser technology (11) product adviser for nanooptical applications	(18) product adviser for nanotechnological applications
Nanoelectronics/ nanoanalysis	(12) specialist for nanoelectronics (13) specialist for mask manufacture (14) optoelectronics engineer	

Qualification profiles contain stated view on knowledge, skills and facilities, which are prerequisite for certain jobs in the nanotechnology sector. They are meant as approaches for the development of measures of intermediate qualification as well as further education and possibly also academic degrees.

The qualification profiles shall be framed modular. A corresponding acknowledgement of degrees even on international level can be guaranteed by the use of recognised score system, analogous to the European Credit Transfer and Accumulation System (ECTS) for higher education. This way transparency and transfer of vocational education and training is promoted.

Qualification profiles increase information and sensitisation of employers, employees as well as the competent authorities. They are suggestions to review and to change current measures of education and training, or to define new qualification measures if necessary. These qualification profiles make no new professions.

Demands for work and qualification can be differentiated into knowledge and skills as well as personal characteristics, and can be described in a form of competences respectively.

In Table 2, the interdisciplinary qualification profile ‘specialist for nanosurface treatment’ is introduced as an example.

Table 2: Interdisciplinary qualification profile (16): specialist for nanosurface treatment

Field of work and operation	• specialists for nanosurface treatment work in companies and in the field of R&D in scientific institutions with the focus on nanocoating • this varied work centres on producing and treating of ultra-thin surfaces in a wide range of application • they are involved during the whole coatings process beginning with the preparation of surfaces and raw materials over carrying out the coatings to the follow-up treatment and quality assurance • besides working in series production they also produce individual items
Points of contact to current qualifications	• existing occupations with physical technical, chemical, micro technological background
Knowledge and technical skills	• thorough knowledge in the field of surface physics and surface techniques as well as surface analyses (e.g. microscopy, spectroscopy, technology of laser measurement) • basis of maths, chemistry and physics with deep knowledge in the field of nano-dimensional surfaces and technology of thin coatings • thorough application-related knowledge in coating and coating procedures • extensive knowledge of materials and their characteristics especially of glass, metals, polymers and ceramics • knowledge of classification and quality standards, for example ISO, as well as instructions, security data sheets, industrial safety and environmental protection • good knowledge of English, technical English
Skills and methodological competence	• carrying out surface coatings with modern machines and industrial plants • specialists for nanosurface treatment master different chemical and physical procedures for coating ultra-thin surfaces, especially in chemical vapour deposition, plasma enhanced chemical vapor deposition, metal-organic chemical vapour deposition and physical vapour deposition, sputtering, arc deposition • moreover procedures such as epitaxy techniques, vacuum coatings, thin film technology, sol-gel-procedure, galvanic separations, coatings und chemical diving procedure are used • coatings on metals and metal compounds, polymers, glass and ceramics are done • they use the industrial systems, instruments and machines for coating (e.g. caster, plasma or sputtering systems) and do control the procedure process with the help of process technology • quality assurance of semi-products and final products by analytical methods of ultra-thin coatings and nanosurfaces
Personal characteristics – social competence	• flexibility • discipline • checking for technical faults • sense of responsibility
others	• reproducible working

5. Conclusions

Nanotechnology is not simply a reduction of existing technologies but bases on other working principles and thinking models from traditional technologies including the microtechnologies. Particular characteristics are the application of quantum effects as well as self organisation processes. Nanotechnological skills and qualifications must pick up this change of paradigms and transfer them into relevant production applications. Potential ethical, medical and ecological aspects of this new technology also have to be taken into account.

Measures to increase public perception and acceptance of the new technology are needed to distribute nanotechnology as the key technology of the 21st century and create conditions to provide qualified staff. Therefore, pupils and students should be supported and motivated. Specific knowledge and qualifications are needed particularly for the production of nanotechnological products and the control of nanotechnological production methods. However it is not recognisable that users of nanotechnological products need special qualifications at present. At this point nanotechnology is basically different from the information technologies that caused broad qualification demands for users.

At present nanotechnology as production technology is in a transitional phase from basic research or applied science to production. In this stage of development only first attempts can be defined about the medium-term demand on employees with a middle qualification. At this time, the large part of research activities in the nanotechnology is reason for the demand primarily of employees with university education. The demand for staff with a qualification below university level is comparatively low. Nevertheless, there is a selective lack of qualified employees below university level already.

With the extension of the nanotechnological production there is a good chance for structure changes in the enterprises. Because of a high level of automation working parts like using functions, quality assurance and documentation will be increasingly assigned to qualified employees with a qualification below university level. New fields of activity occur in the area of marketing and sales. Financial points of view (wage costs) play important role for the assignment of functions to employees with qualifications below university level. However, employees with qualifications below university level required already need particular interdisciplinary knowledge as well as high level of social competences to take part in cooperation and innovation processes in the enterprises.

At the moment the needed knowledge and skill components are mainly offered in a form of additional qualifications building on basic qualifications (professions) in the physical, chemical or biological area. Because of the comparatively low number of persons involved this form of training will further dominate in short term. For the transition period modular training offers or a further educational system are needed. Moreover, increasing demand of employees with qualification below university level (number of person) as well as increasing integration of new knowledge components results in dissatisfaction of enterprises with completion of existing professions by additional qualifications. For the future bases for new professions should be available and have to be created now. Typical features of nanotechnology like the work with quantum effects or processes of the self organisation are in the centre of those professions.

At present nanotechnology is a largely heterogeneous field of research and work with different influences from the areas nanoelectronics, nanochemistry, nanobiotechnology, nanooptics and nanoanalyses. A systemic basis is needed to summarise the variety of nanotechnological appearances and to develop qualification profiles, new occupations as well as modular training offers. Such a systemic approach can be developed by using think models of the general technology.

The international comparisons show an extensive public promotion of the nature scientific and technological research. However only low activities regarding identification and development of the needed human resources can be found. As far as these activities are promoted, they are usually component of the nature scientific or technological research and lead to individual solutions without attention of the neighbouring areas. In the medium term there is danger to cause a shortage of qualified employees. This could be a limiting factor for the successful transportation from nanotechnological research to nanotechnological production.

A noticeable part of the available promoting funds (e.g. 5%) should be used for identification of skill needs as well as for the development and testing of training to prevent obstacles for the economic utilisation of research results trough a shortage of human resources. Risks of emergence of individual solutions are to be met by a systemic approach both for the first education and for the further education. A monitoring programme is urgently recommended to identify skill needs from a qualitative as well as quantitative point of view. The results should be transferred into an action plan for education and training. Additionally the ESF could be used for the development and test of practical training measures. Furthermore, institutions for the occupational education and training, centres of excellence as well as the exchange of best practice in the area of nanotechnology should be more strongly promoted in Europe.

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Emerging technologies – new skill needs in the field of nanotechnology

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1. Introduction

Research on early recognition of skill needs monitors qualification developments, new trends, the dynamics of change and how new qualifications and occupational functions emerge in the workplace. One particular force transforming skill needs is the introduction and dissemination of technological innovations such as nanotechnology, the focus of this article. Nanotechnology is a highly internationalised, interdisciplinary innovation. Hopes for this technology range from the optimisation of existing products and processes to a revolutionary restructuring of production methods and society. A stronger link between technological developments, early recognition research and international exchange must be achieved to ensure the early transfer of information regarding the impact of new technologies on skills and employment. As this article demonstrates, networking within Europe on detecting qualification requirements at an early stage is particularly important for this field.

2. Identifying skill needs early

Vocational training and timely skilling are becoming increasingly valuable because the working world is changing and businesses and employees are confronted with a continual barrage of new demands. Turbulent markets, globalisation and rapid product innovation cycles compel both companies and employees to keep pace to secure their positions for the future. A key factor in an enterprise's success, as well as in improving the employability of individual employees, is proper and sustainable staff training.

Detecting new qualification demands early is an efficient method of deducing which qualification standards companies and workers must have. Studies, observations and analyses facilitating early qualification recognition can help avoid current and future skill deficiencies and adapt vocational training in time. Selecting the appropriate methods and study designs allows forecasts to be made for specific occupations, sectors and fields of activity.

This is why the BMBF launched the initiative on early identification of skill needs. The BMBF initiative promotes various projects with diverse focal points. The FreQueNz ([3]) network has the task of linking individual projects by collecting early recognition research findings and distributing them to its members.

Research surrounding the early recognition of new and future qualification requirements focuses on the following activities:

(a) detecting trends and innovations which affect the skill needs of enterprises and employees;

(b) exploring new qualifications for specific sectors, occupations, jobs and activities;

([3]) FreQueNz (*Früherkennung von Qualifikationserfordernissen im Netz* [Early identification of qualification needs in the Net]) is coordinated by the Fraunhofer IAO. Study results can be found at www.frequenz.net [cited 4.9.2007].

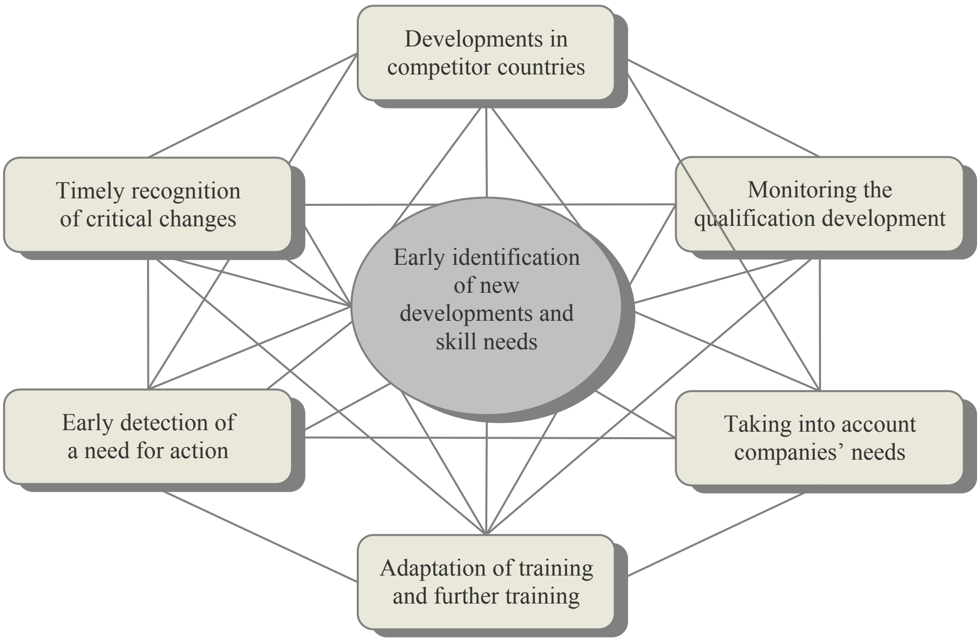
(c) determining deficits and available vocational training options;

(d) elaborating vocational training proposals;

(e) formulating guidelines and recommendations for the vocational training system.

The European perspective has gained significance alongside activities at national level throughout the course of the project because new qualification requirements driven by technical innovations cross regional and national borders. Figure 1 depicts the various approaches and activities.

Figure 1: Early identification of new developments and skill needs facilitates a proactive and timely response to changes



3. Focusing on monitoring qualification development in new technology fields

Early identification of occupational skill needs is an important approach for determining current and future trends and evaluating the impact of new technologies on skill development. It can assist in formulating new initial and continuing training standards for enterprises and workers. The results of early identification research furnish important hints about future occupational fields and increase the sustainability of initial and continuing training efforts. Early recognition also provides businesses and employees with better tools to deal with structural, organisational and technical changes. Findings allow companies to address qualification trends in the workplace at an early stage, boosting the economy's innovativeness and competitiveness.

Thus, one of the main tasks of early identification research is to observe new technologies and their impact on employment and qualifications. The versatility of technologies applied in a variety of areas and sectors has far-reaching effects. Key cross-application technologies include:

(a) information and communication technologies (e.g. wireless Internet, IT security, human-machine interaction interfaces);

(b) microelectronics and microsystems technology (e.g. electronic assistants, language processors, minicomputers);

(c) optic technologies/photonics (e.g. semiconductor lasers, optical information transfer using fibre optics, microoptic data storage and playback);
(d) biotechnology (e.g. polymer display development, new orthopaedic products and procedures, food processing, medical research, new medical products);
(e) sustainable energy technologies (e.g. wind farms, solar facilities, fuel cell systems);
(f) nanotechnology, the focus of the present paper (e.g. microchip production, photovoltaic windows, artificial joints and new materials for the automobile industry for building ultra-light motors and automotive body parts).

In highly innovative occupational fields which develop and implement nanotechnology the importance of international exchange is fast becoming evident. This is because such technologies are developed and used over the world. Global exchange about qualification requirements resulting from new technologies makes it possible to recognise similar developments in different countries. This pertains to the driving forces behind changes in qualification needs and to the challenges these transformations pose for national vocational training systems. Thus, considering the European standpoint bolsters European, national and regional activities.

It is not only in core branches that technological innovations prompt job skill needs. As these technologies mature through practical application and become more widespread, they also require continued learning on the part of the companies and employees who work with them and are responsible for value-added processes. This applies to all functions within the company, for example sales and service, and not just to employees such as technicians, engineers and master craftspeople who are already highly skilled.

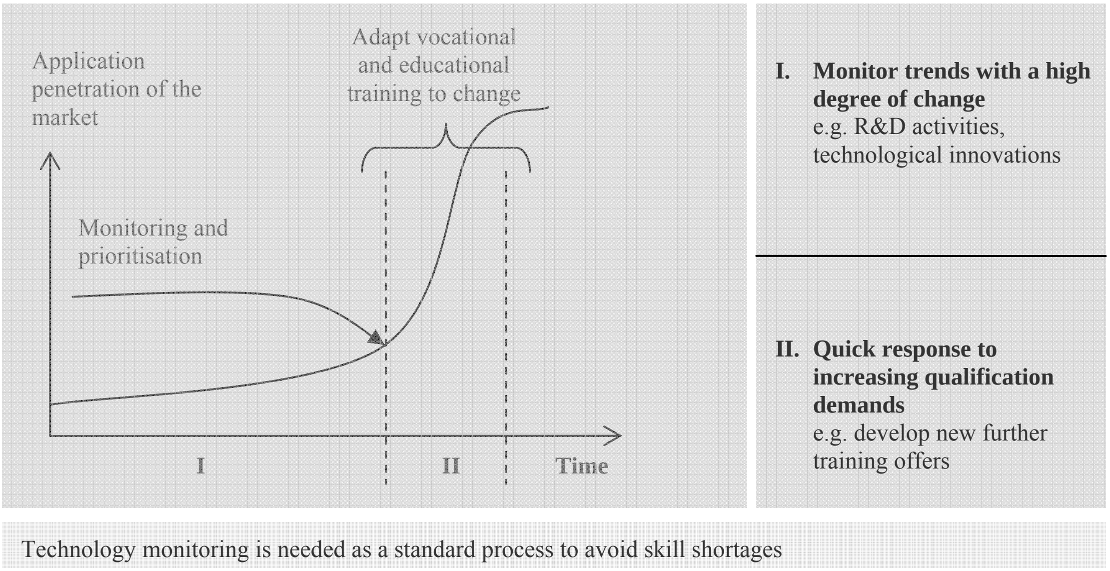
Monitoring and researching the development of new technologies and their dissemination, as well as the maturity levels and market presence of new products, is crucial. This allows new qualification requirements for workers and enterprises to be evaluated in terms of concrete formulation and time frames. This evaluation must be based on systematic monitoring of selected technologies which pertain to job development. The focus must be to observe and assess trends from a skill and vocational training research point of view. Monitoring methodology follows the steps described in Figure 2:

(a) monitor trends with a high degree of change: new product and process analysis is central to monitoring technological innovations, their maturity level and market diffusion. When new products and services will enter the market can be inferred from such analysis;
(b) quick response to growing qualification demands: when new technologies, products and services are nearing market maturity, it is necessary to determine related skill needs and when these must be met.

As soon as new qualification needs have been inventoried, suitable education and continuing training measures must be conceived and made available. Recommendations for action must be developed for the initial and continuing education and training system when fundamental, sustainable changes are to be implemented.

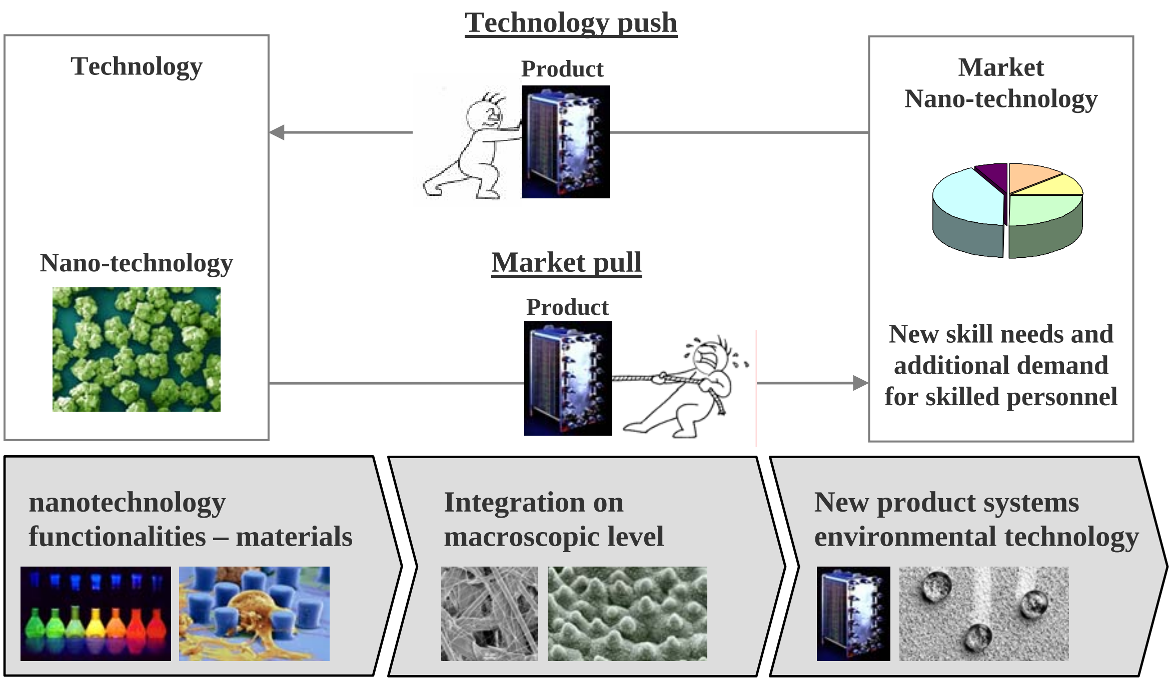
To avoid qualification deficiencies when technological innovations arise, it is important that qualification development in practice is examined at the same time as business segment, sales market and sales figure analysis and observation. New skills gain relevance in the workplace as new products and procedures mature. Pairing the methods and procedures of early qualification recognition at the operating level with the findings of technology monitoring should equip enterprises and those responsible for vocational training to predict the content and quantity of future shifts in skill requirements and provide employees with timely training support, averting a slowdown in operational innovations. Early training of employees, for example when expanding new business segments or introducing new technologies, is an important variable which is seldom sufficiently considered.

Figure 2: Using early recognition of skill requirements to quickly adjust the (continuing) training system



It can be assumed that two factors will influence the market when a new technology is established: 'technology push', i.e. new processes and products are marketed by agents of innovation in the science and technology fields, and 'market pull', i.e. the market welcomes the replacement of existing procedures, products and components with new ones. This mechanism is illustrated by the example of nanotechnology in Figure 3.

Figure 3: Nanotechnology functionalities and the market



4. New challenges for vocational training posed by nanotechnology

Nanotechnology is counted amongst the key technologies of the 21st century. Key technologies are defined as those which shape competitive strategy and are integral to the technological spectrum. Nanotechnology gives materials and constituent parts functions and properties which can only occur at the nanoscale ([4]) (10^{-9} m) to construct nano-sized structures with a predefined range of functions. This functionalises and miniaturises materials and surfaces. Nanotechnology is relevant to a wide range of fields: it is neither a scientific discipline in itself nor is it a defined area of application. It deals with systems which rely solely on the benefits of nanoscale components (Bachmann, 1998).

Nanotechnology encompasses a variety of interdisciplinary sciences. No universally valid differentiation has been established in research or practice (see also Hullman, 2001). However, the following classification according to subdisciplines is helpful (Bachmann, 2002):

(a) nanoelectronics,

(b) nanooptics,

(c) nanofabrication,

(d) nanomaterial science,

(e) nanochemistry,

(f) nanobiotechnology,

(g) nanoanalysis.

To date no product has been manufactured exclusively through nanotechnology. Implementation of nanotechnologies does not entail radical innovation in the form of new products or applications. Rather they further develop or optimise existing products which compete directly with others already on the market (Baden-Württemberg Ministry of Environment and Transport, 2004). Industries most frequently integrating nanotechnological processes, components and products are: chemistry, materials and manufacturing; environmental protection and energy, electronics and computers; medicine and health care; aerospace and automotives (Hyder, 2003).

The expectations of nanotechnology range from optimisation of existing products and processes to revolutionising production methods and society. This prediction assumes biotechnology, nanotechnology and information technology will merge. A comprehensive forecast study by Siemens and TNS Ingrates (Wienholt and Ladic, 2004) identified the chief spheres nanotechnology impacts as:

(a) invisible intelligence: IT penetrates every facet of daily life. Nanotechnology has made significant contributions to new data-processing methods which network electronic devices while incorporating ubiquitous computing. In the future, functions once performed by transistors and circuit and storage elements will be performed by significantly smaller nanoelements;

(b) quantum mechanics dominates circuit design. Quantum mechanics exploits special phenomena which only occur on the nanoscale to create smaller, improved and/or faster electronic components;

([4]) The word nano comes from Greek and means ‘dwarf’.

(c) photonics is finding commercial applications. Photonics enables electronics to employ light rather than electricity;

(d) molecular prosthetics repair and strengthen cell molecules. Researchers in this field have achieved a better understanding of how cell proteins function and engineered nanomolecular structures which attach themselves to defective proteins and restore their original structures and functions;

(e) implantable, biocompatible nanomaterials provide custom-fit replacement parts for the human body. Surgical implant procedures and sophisticated software which model and simulate nanoscale cell reactions as well as nanomaterials open up new prospects for medicine;

(f) using nanomaterials as carriers for pharmaceuticals and other therapies. Using nanomaterials to deliver drugs and other therapeutic preparations makes it possible to develop carriers which fulfil specific requirements regarding the scope of treatment, biocompatibility and biodegradability;

(g) biosensors recognise and measure biological reactions at the nano level. Haematology is just one area employing biosensors. They are used to detect biomarkers of heart attacks and strokes and to monitor drug delivery. They can also be used to monitor infectious diseases and hormone levels and to determine blood cell types.

Nanotechnology is expected to have an impact on nearly every industrial sector and thus influence many economic spheres. Although many areas of application are still in the research phase, a myriad of product innovations have already found their way to the marketplace (e.g. scratch-resistant car paint, sun cream containing nanoparticles, nanomembranes for energy and environmental technology, nanoparticles for tyres).

The Institute for Structural Policy and Economic Development (isw) in Halle (see article in this issue) has developed a matrix to record and describe developments. The system will systematically detect new skill demands created by applied nanotechnology. The main systematisation criteria are: process of change, area of procedure, nanoindustry, centre of competence, job system, system of qualification, products (Abicht et al., 2006). The isw research facilitated the design of additional training modules for laboratory workers. The early recognition project ([5]) also involved the vocational training department at the Jülich Research Centre. Module components are already being applied in training. The project's findings were also incorporated in the nanosurface-coating continuing training module developed with researchers at the *Magdeburger Forschungsintstitut für Fertigungsfragen e.V.* (Magdeburg Manufacturing Research Institute) and University of Magdeburg professors.

Early detection research results for new technologies contribute significantly to human resource development and strengthen the innovativeness and competitiveness of companies and the whole economy. Determining new and future qualification needs would benefit SMEs and their employees in affected industries because these companies rarely have their own continuing training divisions. Achieving this goal requires a closer link between technological developments, innovation policy and early recognition research. Only a well-trained workforce can stay innovative and competitive and thereby secure existing jobs and create new ones. Beyond this, taking part in European early skill recognition activities permits knowledge and experience transfer with other countries.

([5]) Identification of trend-setting qualifications in the nanotechnology sector.

5. Outlook

The main objective of early recognition activities is to help update continuing training and modernise initial training. Statistics and projections are useful in formulating policy, yet they cannot adequately determine new qualification needs in the workplace. They must be supplemented with targeted technology and innovation monitoring procedures and bottom-up approaches which focus on particular areas, technological developments, sectors, regions, occupational fields and target groups. Identifying new qualifications and skills is not possible without direct reference to current developments in the real world of work.

Various methods are employed to ascertain future trends and deduce new demands on companies and workers. However, the methods and processes of early skill recognition should not be confused with prognosis research procedures. While prognosis research aims to improve vocational training planning and formulate training systems and curricula, the goal of the early identification of skill needs is to detect new and future qualifications and to quantify them. The task is to profile transformation processes in job training rather than to predict likely developments (Grollmann, 2005).

Early identification of skill needs is an important element in reducing structural imbalances on the job market and avoiding unemployment caused by structural discrepancies between training measures and training needs. Further, the systematic approach taken to identify qualification requirements lays a foundation for supplying companies with a skilled workforce and averting letdowns and costly restructuring. This in turn bolsters job seekers' employability and increases the innovative and competitive capacities of enterprises and the whole economy. Attaining this goal requires forging a closer link between technological developments, innovation policy and early skill detection research. The main objective of this link should be to accelerate the productive transfer of R&D activities to the economy. A well-trained workforce ensures innovativeness and competitiveness and thereby guarantees existing jobs and creates new ones. Training institutions and policymakers profit along with employees and businesses from the early recognition of future skill needs.

Cross-sectoral, highly internationalised fields in particular, such as nanotechnology, require intensified international information exchange on future qualification developments. Networking in the early identification of skill needs at the European level promotes such an exchange of information, experiences and research findings, facilitating reciprocal learning among the participating countries.

This is why skills development in nanotechnology inquire into these five questions:

(a) what are the trends in the nanotechnology sector and how do these trends affect skill needs and occupational profiles?

(b) how do these trends affect other sectors and activities (and their skill needs and occupational profiles)?

(c) how can we identify future skill shortages and gaps in emerging technologies?

(d) what specific shortages and gaps have already been identified/predicted for the nanotechnology sector?

(e) how can skill shortages/skill gaps be tackled and possibly prevented?

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Part II:
Skill needs in nanotechnology: country examples

Jan Voves
Trends and skill needs in the field of nanotechnology – the state of affairs in the Czech Republic in the European context

Wolfgang Luther
Nanotechnology training needs from the German perspective

Trends and skill needs in the field of nanotechnology – the state of affairs in the Czech Republic in the European context

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1. Introduction

Nanotechnology is the manipulation or self assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new properties. The prefix 'nano' is from the Greek word meaning 'dwarf'. This dwarf has a 'magic power'. Nanotechnology opens a completely new world of opportunities and solutions in all kinds of areas: the field of diagnostics and analytics, textile industry, energy sector, electronics and automotive industry. Nanotechnology may be a key capability helping industry to become more efficient and competitive. The Czech Republic recognised the potential of nanotechnology at an early stage and started to develop a strong effort in nanosciences. There are crucial needs to ensure the responsible education in nanotechnology including interdisciplinary research and education, the establishment of the respective infrastructure, training in advanced production technologies, and implementation of environmental, health, and ethical aspects.

2. Trends in the nanotechnology sector

To realise enormous potential of nanotechnology, it will be necessary to replace present-day production technology by new nano-manufacturing techniques. These will essentially involve the self-assembly of molecules into configurations that produce specific functionalities. At present, following three main sectors dominate the world of nanotechnology.

2.1. Nanomaterials

The area of dispersions and coatings of nanoparticles is the most mature area of nanoscale science and technology. Some examples of the present technological impact of nanostructuring are thermal and optical barriers, imaging enhancement, ink-jet materials, coated abrasive slurries, and information-recording layers. There appears to be very strong potential impact in the areas of targeted drug delivery, gene therapy, and multifunctional coatings.

High surface area materials are another example. A nanoparticle 5 nm in diameter has about half of its atoms on its surface. If the nanoparticles are then brought together in a lightly assembled way, this surface area is available for a variety of useful applications. Already there are numerous commercial applications in porous membranes or molecular sieves, drug delivery, tailored catalysts, and absorption/desorption materials. Future technological potential is seen in the areas of molecule-specific sensors, large bacterial filters, energy storage, and Grätzel-type solar cells.

2.2. Nanobiotechnology

Nanoscale engineering is being combined with biology to manipulate living systems directly or to build biologically inspired materials and devices at the molecular level. This has the potential to bring many health-related innovations – from precisely targeted drugs and drug delivery systems, to increasingly biocompatible implants and prosthetics. Single cell analysis and treatments can be imagined. Biomolecular analogues also hold out tremendous promise in areas such as molecular computation, optoelectronic devices and bioelectronics. Proteins can be built into complex molecular structures – but as yet it remains to be determined how they can be constructed, used and powered.

2.3. Nanoelectronics

The critical dimensions of the electron devices are fast streaming to the nanometric range. Therefore, the new quantum effects appear in the nanoelectronic devices: discrete electron energy states in the nanometric quantum wells, electron tunnelling through the thin potential barrier, electron wave function interference, Cooper pair tunnelling known as Josephson effects. These effects enable to develop the devices with a new functionality and performance. In other words we are entering the realm of quantum mechanics and it is different from the classical mechanics that we encounter in everyday life.

Nanotechnology will have potentially significant impacts on energy efficiency, storage and production. It can be used to monitor and remediate environmental problems; improve control emissions from a wide range of sources, and develop new, 'green' processing technologies that minimise the generation of undesirable by-products. The impact on industrial control, manufacturing and processing will be impressive and result in saving energy. Potential future breakthroughs also include use of nanorobotics and intelligent systems for environment and nuclear waste management and for defence applications. A key understanding of nanotechnology is that it offers not just better products, but a vastly improved means of production. That's the real meaning of nanotechnology, and why it is sometimes seen as 'the next industrial revolution'. Nanotechnology will not create a single nanoindustry. Instead, the technology will become integral to many industries and affects everything, analogous to electricity.

3. Impacts on the public health, safety and environmental protection

Moving into the nanoworld will allow virtually total control of matter. But this in turn raises questions about ethics and the possible risks involved. Taking into account that nanoparticles have a greater reactive surface area per unit mass than larger particles, their toxicity and potential health effects may also increase. There is, therefore, concern about the potential impact of nanoparticles on human health and the environment. All applications and use of nanotechnology must comply with the high level of public health, safety, consumers and workers protection, and environmental protection. Possible ethical issues include non-therapeutic human enhancement or invasion of privacy due to invisible sensors. Adequate transparency in research is essential, and a safe set of rules must be put in place. Unlike nuclear energy, much nanotechnology development is in the hands of private companies that are beyond direct public control. Public power, through politicians and public opinion, should therefore have the cultural instruments and access to appropriate qualified expertise to assess, steer and – where appropriate – constrain developments. Also, a 'nano-divide' may arise between those countries or regions that understand the new technological approach and those that do not.

4. Impacts on the jobs, education and training

Advent of nanotechnology is a boom time for jobs for the science and engineering workforce. In addition, there is need for supporting labour services, which will create job opportunities for other workers. Even the most high-tech industry hires many persons in sales, clerical and office work, and employs service workers of different types. But as the technology matures, two competing processes begin to affect jobs. The technology reduces the number of workers needed to produce a given level of output, and lowers the cost of products, which increases demand for goods and expands jobs. Due to the cost-reducing effect of nano, we should not think of nano as a job creating technology but rather as a productivity enhancing technology that permeates the economy. Nanotechnology will create some new jobs, but that will not be its main contribution to job growth. Its main contribution will be manufacturing efficiencies that improve real wages and living standards. These gains will in turn generate additional consumer demand for all sorts of products and thus contribute to the growth of employment.

In proportion to the expected penetration and impact of nanotechnology into industry and society, current numbers of people with the requisite skills are far too limited. The European Survey in 2004 clearly shows an urgent need for development of nanotechnology education and training. Almost one-half of the respondents foresee a shortage of qualified personnel needed to advance nanotechnology within 5 years, and another quarter in 5-10 years. Meeting the anticipated need implies a new approach to education and training. To stimulate future interest for the intellectual challenges of science and research, observation, analysis, interpretation, abstraction and prediction skills have to be developed in primary and secondary schools.

Successful R&D efforts rely on teamwork and communication. A complicating factor for the nanotechnology effort is the interdisciplinary (or multi-disciplinary) nature of the work, which requires communication across technical and scientific fields, focusing on physics, chemistry, biology, toxicology and ecotoxicology and engineering, but also including entrepreneurial studies, risk assessment, and social and human sciences where appropriate. Each of the sciences and engineering represent distinct ways of seeing the natural world, with different jargon, culture, and analytical tools. Nanotechnology workers must possess sufficient understanding of more than one discipline to promote efficient communication. The creation of a new breed of researchers working across traditional disciplines and thinking ‘outside the box’ is an absolute necessity for the field of nanostructure science and technology to truly reach fruition and to impact society with full force.

The existing tertiary education system tends to compartmentalise by disciplines for example physics, chemistry, engineering or biology. As a result, many scientists are finding that they have gaps in their education. Putting together specialists with different backgrounds is not necessarily the optimal solution. A new generation of scientists, engineers and technicians is required, with broad knowledge of physics, chemistry, biology and engineering, as well as of the basic principles of manufacturing and control. No one can become an expert in everything. Specialists nevertheless need to be able to work together, developing a common language and modes of interaction that will permit an integrated exploration of nanotechnology. A distinction should be made between first (bachelors) and postgraduate degrees in nanotechnology. While it is admirable to attempt to produce a kind of renaissance scientist, i.e. a master of many disciplines, it is still unknown whether a three of four year taught course at the first degree level will allow students to gain the required level of expertise in any discipline to be useful to future employers, or even in an academic career. There is currently some debate among academics as to whether it would be better to have a sound understanding of one area of science first and then broaden this to include other disciplines. This is not the case with postgraduate courses. Many of the post-graduate degrees are specifically designed to give scientists and engineers the multidisciplinary skills required to get to grips with nanoscience and nanotechnologies. Some courses go further, adding elements of entrepreneurship or business skills, and ensuring that graduates are much in demand by employers.

Apart from recruiting young people, continuous training will have to be considered. Reorientation courses, summer schools, and workshops could be envisaged for the existing workforce. Mid-career post-doctorates might prove a powerful tool – while international cooperation represents another important stimulus.

5. Infrastructure and European poles of excellence

On 12 May 2004 the Commission adopted the Communication Towards a European Strategy for Nanotechnology in which a safe, integrated and responsible strategy was proposed. World-class research and development infrastructure and 'poles of excellence' are essential for the EU to remain competitive in nanotechnology. Europe needs an appropriate, diverse but coherent system of infrastructure that comprises both 'single sited' (in one location) and 'distributed' (networked) facilities. However, due to its interdisciplinary, complex and costly nature, the infrastructure nanotechnology requires a critical mass of resources that are beyond the means of regional and often even national governments and industry. Special attention will be paid to the needs of industry, in particular SMEs, so to reinforce cooperation and technology transfer from academic teams to conceive advanced prototypes and validate them in industrially relevant environments. SMEs and regional technological clusters integrating industry, research institutes and universities can play a crucial role in particular at regional level. The new 'regions of knowledge' initiative could contribute towards establishing effective clusters and networks.

Poles of excellence can bring together faculty members of different disciplines under a single organisation to foster interdisciplinary research and collaboration in nanotechnology. Often, these researchers will retain a desk at their 'home' department. It is common for a nano-institute to have representatives from 10 or more home departments. Policy-makers must insure that the long-term supply of talent and ideas is not sacrificed to satisfy short-term demand.

An important educational mission for nanotechnology poles-of-excellence is the retraining of professionals. Many scientifically trained graduates have left scientific fields in favour of positions in finance, management or other non-science related jobs. Many students have become disillusioned with the sciences as a career option. This supply of disenchanted students could be reenergised by the promise of nanotechnology. With the proper cross-disciplinary training, they could be prepared to meet the extra demand from nanofirms. Even in times of increasing partnerships between corporations and university, basic research remains the essential element to technical infrastructure. Knowledge flows primarily from academic labs to industry. Industry firms do not readily profit from investing in basic science since the risks are high that any specific research effort will have no commercial value in any reasonable time period. But because the overall body of knowledge is so valuable, there is a temptation to allow industry to control it or to dictate the direction of academic research to bring faster returns. Some might argue that such a practice could even reduce the government's burden for funding academic science. This would be a dangerous strategy. Even if industry firms can afford to divert significant funds to university research, and even if they are very good at picking research topics, firms have a strong incentive to restrict the knowledge that they help to create, which would result in a slowdown of the overall pace of basic research.

6. Nanotechnology education in the Czech Republic

The Ministry for education, youth and sports is responsible for the health and continued vitality of the nation's science, technology and engineering education, and for providing leadership in the effort to improve education in these areas. The research and development council of the government is responsible for shaping the R&D system. There are five national grant agencies, which fund research. Traditionally, the institutes of the Czech Academy of Science carry out larger part of the research, and the universities are more responsible for higher education. In April 2003, the Czech government approved the National Research Programme for 2004-09. It consists of five thematic programmes. The thematic programme No 3 'Competitiveness in Sustainable Development'. This thematic programme has six subprogrammes. The subpro-gramme on manufacturing processes and systems includes the key research direction electronic and photonic materials and structures, which also focuses on nano electro mechanical systems (NEMS), molecular electronics, new carbon and biomimetic materials. The subprogramme on emerging technologies includes the key research direction nanotechnologies and nanomaterials. Currently there is no specific State programme supporting the related research and development and no specific study programme (or curricula, specialisation or course) focusing on nanotechnology at Czech Technical Universities. Nanoscience and nanotechnology are only partially included in courses like physics, chemistry, physical chemistry, electronics, materials engineering, etc.

To realise the mentioned potential of nanotechnology research, the Czech Republic needs a population of interdisciplinary researchers and engineers who can generate knowledge and ensure that this is, in turn, transferred to industry. To meet the need of the nanotechnology infrastructure of research and education at the national and international level, new and existing nanotechnology networks are developed and shared. A hierarchal infrastructure has recently been completed:

(a) at university level: Centre Nanotech CTU was established in 2004 as a workgroup for micro- and nanotechnology of the Czech Technical University. Continuous communication between teams of different but complementary research profiles will result in advances for future application of nanotechnologies and in the improved education in nanotechnology, especially in the PhD study programmes;

(b) at national level: the Czech Society of New Materials and Technologies was founded in 2002. Its nanoscience and nanotechnology section with more than 100 members with several working groups including the working group 'education' organise the network of Czech universities with the aim to build up the infrastructure for experience exchange in education and research, to establish new courses and curricula in the field of nanotechnology, to encourage the collaboration with the Czech Academy of Science, etc. The research group Nano-team was formed by about 17 scientists, each representing a group of 3-20 researchers, experienced in different areas of the physics of nanostructures and nanotechnologies. Importance of the physics is due to the fact that it forms background of new tools – atomic force, scanning tunnelling and electron microscopy, opening doors of nanoworld characterisation for biology and chemistry on atomic or molecular level. The Nano-team is basis for projects on national and international level. In addition to high level research collaboration important goal of Nano-team is to contribute to the education of nanosciences at different levels. Prague seems to be a new pole of excellence. All groups in this region are cooperating in preparation of a new Institute of Applied Sciences. There are four main proposed research areas in the Institute of Applied Sciences: nanosciences, special chemistry, new energy sources and applied mathematics. Institute will concentrate expensive equipments for the electron lithography and nano characterisation techniques. Mainly PhD students will take part in the Institute of Applied Sciences research;

(c) at European level: Network for nanostructured materials proposed by 10 Centres of Associate Candidate Countries (NENAMAT) (also including the Czech coordinator in the Technical University in Brno) was founded in 2004 to improve the knowledge base of application-oriented nanosciences and technology and to help in building the European nanotechnology related industry. The MNT ERA-NET (micro- and nanotechnology European research area network) integrates nanotechnology programmes of new participants into the already existing network. The Czech Republic is planned to be included as an associated member. The Czech Society of New Materials and Technologies plays a central coordination role in the process of implementation. The planned activities include the systematic exchange of information about programmes, implementation of joint activities, cooperation programmes, transnational research activities, and the institutionalisation of cooperation;.

(d) at global level: the Czech Republic is already a member in the global group of experts involved with nanotechnology from 25 countries, which first met for the 'international dialogue on responsible research and development of nanotechnology' in June 2004 in Alexandria, Virginia, USA. The National Science Foundation USA, EU and Japan will continue to organise future meetings of the expanded group. The Czech Republic has been nominated into the group, which is responsible for conceptual education for nanotechnology.

7. Summary

Interdisciplinary research and education is the most important aspect in nanotechnology. Universities should introduce courses based on nanoscale science and integrate nanotechnology with physics, chemistry, biology, electronics, medicine, engineering and other fields. To meet the needs of the research and education in nanotechnology the infrastructure at the national and international level has recently been formed. Poles of excellence will play a central role in the development of the knowledge society needed for the nanotechnology. International collaboration and academy-industry cooperation is necessary. Due to the fact that manufacturing at the nanoscale has potential to decrease the consumption of energy, water, materials, waste, contaminants and because some nanotechnologies include also serious potential risks, nanotechnology education must also include environmental, health, ethical, and legal aspects.

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Nanotechnology training needs from the German perspective

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1. Introduction

Nanotechnology is considered one of the key technologies of the 21st century. The future competitiveness of the products of many major industries such as automobile manufacturing, chemicals, pharmaceuticals, IT and optics depends on their ability to tap the potential of nanotechnology. Nanotechnology also opens up new market opportunities for smaller, quicker, more efficient, 'intelligent' system components for new products with greatly enhanced and sometimes entirely new functionalities. How widespread these optimised or new products based on the insights of nanotechnology will be depends, however, on whether manufacturers and users of the technology possess the necessary knowledge to produce and employ these nanotechnology systems components. The interdisciplinary nature and rapid development of nanotechnology will thrust the education system and learners into uncharted territory as far as course programmes, training modules and course structuring are concerned. New approaches must be taken to cultivate team skills, language skills and media know-how. To ensure nanotechnology can rely on an adequate supply of skilled workers in the future, we must establish the right structures now. This is of particular importance for Germany, where the availability of skilled workers is jeopardised by demographic trends such as a shrinking and ageing population. This article will discuss how potential skill deficits in nanotechnology can be identified and what measures may be able to counter the threat of labour shortages in nanotechnology, by looking at the example of optical technologies. This burgeoning field is currently more advanced than nanotechnology. The article also presents initial approaches the German Federal Ministry of Education and Research (BMBF) is taking to identify skill deficits in nanotechnology and ways to avoid them.

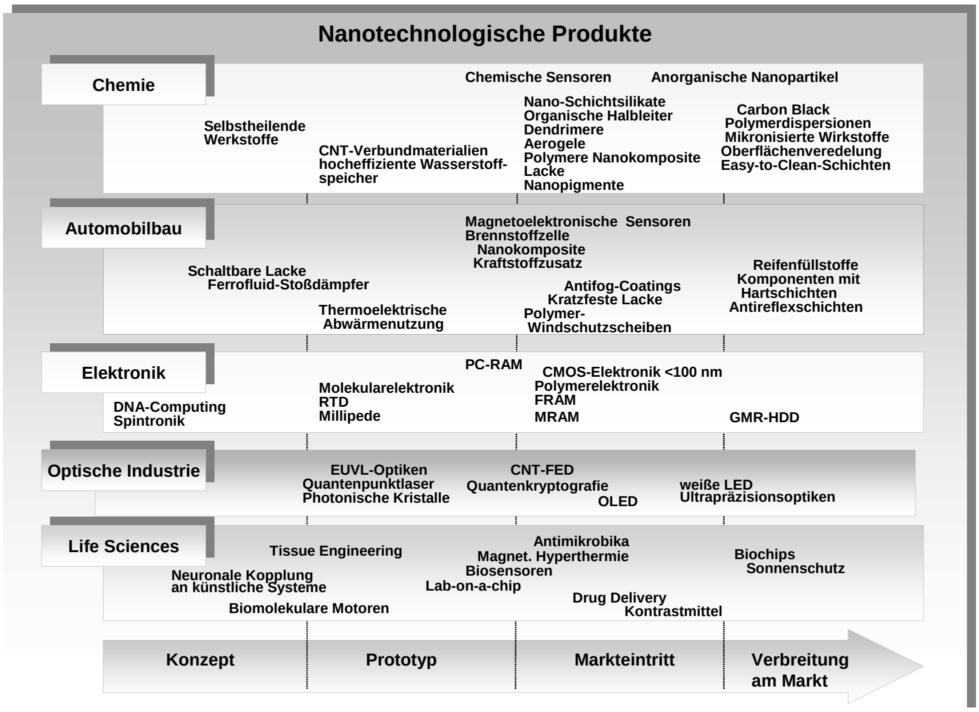
2. Nanotechnology innovation potential

Nanoscale components are already improving the competitiveness of numerous mass-produced ICT devices (e.g. the latest-generation memory chips, hard drives, CD and DVD players), medical technology (e.g. diagnostic biochips) and chemicals (e.g. additives in cosmetics, polishes, automobile tyres and packaging). Nanotechnology is leveraging a global market currently worth around EUR 100 billion. Various forecasts predict a spectacular increase in this market volume over the next ten years. Although many products with nanoscale components are already established on the market, most nanotechnology innovations will not be commercially viable for several years, in some cases for several decades. Figure 4 surveys the current status of nanotechnology products and product options in various fields of application (Luther and Zweck, 2005).

Public funding of nanotechnology in Germany amounted to around EUR 290 million in 2004. Most came from the BMBF. This underlines the significance nanotechnology has for securing and strengthening Germany's economic and research position. Many hopes for the creation of secure jobs are attached to nanotechnology. The number of jobs in the 450 existing nanotechnology firms in Germany is expected to increase by 10-15000 by the year 2006

(Luther et al., 2004). Although it is not possible to determine the exact number of employees in the nanotechnology sector, we can make an educated guess that even now several tens of thousands of jobs in Germany directly or indirectly involve nanotechnology. This is bound to have implications for the initial and continuing training markets. We must investigate how to furnish workers with the required nanotechnology skills in the future and devise measures for modernising existing training professions and continuing training programmes and for defining new occupations and additional qualifications.

Figure 4: Beispielhafter Überblick zum Entwicklungsstand verschiedener Nanotechnologieprodukte und -produktoptionen in unterschiedlichen wirtschaftlichen Anwendungsfeldern



Source: VDI TZ

3. Future shortages of skilled workers in technical occupations

German industry is already suffering from a lack of adequately qualified workers in technical occupations. A survey by the *Institut der deutschen Wirtschaft* (Institute for German Economics – IW) now considers lack of personnel a greater hurdle to innovation than lack of financial resources (IW, 2004). Sectors with a large number of highly qualified workers, usually including specially trained engineers, are particularly vulnerable to this labour shortage. In the long term this development will put Germany at a strategic competitive disadvantage on national and global markets. SMEs with fewer than 100 employees will be particularly hard hit. Germany's demographic changes will aggravate this situation and will probably lead to a shortage of university-trained personnel in IT, natural sciences, etc. There are currently more people aged between 25 and 34 than between 55 and 64. In 2020, however, the older age group will outnumber the younger by 10:6. By that date at the latest, the majority of companies will face the lack of skilled workers already lamented by over a quarter of all German enterprises. The situation is particularly acute for the mathematics, IT, natural sciences and technology (MINT) occupations – there will be a severe shortfall of qualified personnel in MINT. In recent years Germany has recorded negative trends in all these areas, which are so important for economic growth (VDI, 2005):

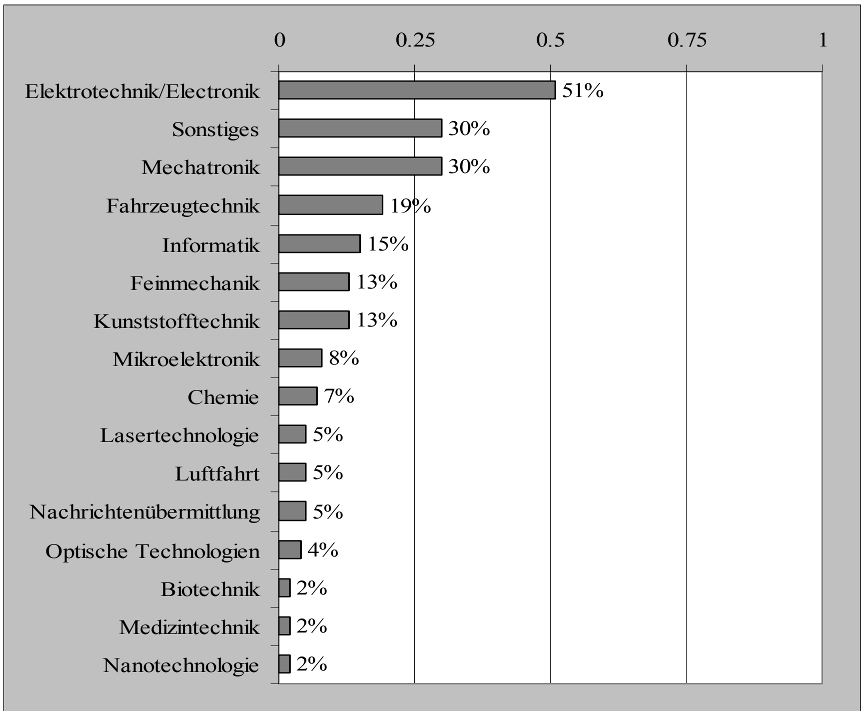
(a) the ratio of MINT graduates to 25-34 year-old employees remained roughly constant in Germany from 1998 to 2002 while other leading economies increased their crop of MINT graduates. Finland, the UK, France and Australia boast more than twice as many MINT graduates each year as Germany, as a percentage of workers aged between 25 and 34;

(b) the number of engineering graduates sank in Germany by around 18% between 1998 and 2002 while the figure increased dramatically in most OECD countries; by over a third in Finland, by 41% in Poland, by 44% in Austria and by an impressive 68% in Sweden. The demographic transformation makes it imperative that we encourage more young Germans to study engineering;

(c) only 27% of engineering college graduates in Germany are women. This is below the international average. In the UK, France, Sweden and the US women make up over 35% of the group.

The looming lack of skilled technical personnel in Germany is, therefore, particularly alarming. Although companies have, for the time being, only noted workforce shortages in traditional technical fields such as electrical engineering, mechatronics and automotive engineering (VDI/ZEW, 2003) (Figure 5), new areas such as nanotechnology clearly require early recognition of skill needs because of their dynamic growth. We must also quickly identify possible methods for avoiding future skill deficits, particularly since in the next ten years even conventional sectors such as mechanical engineering and vehicle construction will have to embrace nanotechnology to remain competitive.

Figure 5: Ergebnisse einer Unternehmensbefragung zur Frage in welchen Bereichen im Unternehmen in den nächsten 5 bis 10 Jahren ein Ingenieurmangel auftreten könnte (N= 332)



Source : VDI Nachrichten/ ZEW 2003

4. Skill needs in nanotechnology

New technologies require new knowledge and new skills. Employees will use the methods of nanotechnology more and more in their working life, to exploit them for maximum benefit (Rieke and Bachmann, 2004). Companies will be clamouring for workers with superior know-how. A good first degree alone will not be sufficient. The significance of lifelong learning and continuing vocational training will increase. This not only affects existing research companies and their employees; start-ups in research-intensive sectors also rely on staff with the relevant superior qualifications. Particular attention should be paid to training masters and technicians in the research-intensive manufacturing industry, as they often later become self-employed and could lose touch with developments. University graduates tend to become entrepreneurs in the more knowledge-intensive service sector. The early identification of occupational skill needs can help counter potential workforce shortfalls. However, there are currently no corroborated findings on future professions in the nanotechnology sector. Therefore, the BMBF is running in-depth analysis of skill needs and of the possible course content of initial and continuing training in nanotechnology. Strategies to increase the acceptance of continuing training are also needed, since only around 10% of workers in all technical fields are currently enrolled in continuing training. Early recognition of new occupational fields and qualifications, and modernisation strategies for existing ones, to encompass nanotechnology processes, and targeted structuring of appropriate training measures can significantly strengthen Germany's nanotechnology capabilities and competitiveness. We must also encourage interest in natural sciences among schoolchildren, particularly girls, to address the need to increase the ratio of women in engineering and technical professions and university faculties. The nanotechnology competence centres established by the BMBF are already holding events such as nanoscience nights with pupils and further training seminars for teachers, to make them aware of career prospects at an early stage. Other BMBF projects in the area of nanotechnology and innovation are:

(a) the nanotruck travelling exhibition ([6]), which attracted over 100 000 visitors at over 200 different locations in 2004;

(b) a nanotechnology brochure for schoolchildren and the general public, which has now been translated into all EU languages by the European Commission ([7]);

(c) an interactive journey into the nanocosmos to help make school pupils enthusiastic about nanotechnology ([8]);

(d) teaching materials, produced in collaboration with the *Schulen ans Netz* (schools on the Web) initiative;

(e) listing categorised nanotechnology continuing training options in the KURS course database, produced in cooperation with the Federal Labour Office ([9]);

(f) Internet compilation of university courses, vocational trainers and continuing training institutions which address nanotechnology ([10]).

5. Identification of future skill needs, in the German optics industry

Although initial measures for avoiding future nanotechnology skill deficits in Germany have already been set in motion, it is helpful to seek guidance from the experiences that other fields

([6]) Available from Internet: http://www.nanotruck.net [cited 6.9.2007].
([7]) Available from Internet: http://www.cordis.lu/nanotechnology/src/pressroom_films.htm#brochure [cited 6.9.2007].
([8]) Available from Internet: http://www.nanoreisen.de [cited 6.9.2007].
([9]) Available from Internet: http://infobub.arbeitsagentur.de/kurs/index.jsp [cited 6.9.2007].
([10]) Available from Internet: http://www.nanonet.de [cited 6.9.2007].

have had, particularly those which are currently more advanced. One such field is optics. The German optics sector is dynamic and pioneering. In Germany 110 000 people are employed in the manufacture of optical components and equipment. In the last few years 50 000 new jobs have been created (BMBF, 2004). The BMBF has a programme to support the optics industry to the tune of EUR 280 million. Innovation processes requiring future-oriented employees and tasks are not only shaped by research and development but also by the environment in which they arise (Baron, 2004).

The BMBF has initiated various activities to identify skill needs and training options within the optics field. Its studies focus on SMEs, craft trades and large companies.

A method mix of representative telephone interviews, expert surveys and case studies provided a comprehensive overview of skill needs and qualification options available in Germany. A key finding of this study (Abicht et al., 2004; Novello-von Bescherer, 2005; Fischer et al., 2005) was that:

(a) in large companies in-house training sessions are of central importance alongside basic academic education. The workshops are often led by experienced colleagues from research and development. More conventional teaching methods are rarely employed to fill specific knowledge gaps. Instead companies are experimenting with new forms of knowledge transfer which are more practical and job-based. An optics company can secure core competences for product innovation only through the broadest possible interdisciplinary composition of its academic personnel. Optics product development calls for project teams uniting optical electronics engineers with, for example, physicists, materials scientists, chemists, mechanical engineers, precision engineering technicians and/or IT specialists. Large companies are pushing for all academic courses to concentrate on the basics of optical technologies and their interfaces with associated fields. Companies feel that it is their responsibility to provide each new generation of university-trained recruits in the field with specific specialist training, not least because they are usually the leading experts in their scientific field;

(b) in craft trades optical technologies are relevant for more than 60 of a total of 94 occupations. Optical technologies are used as tools and means of production in craft trades but are also found in products and services. BMBF supports the widespread use of optical technologies, particularly lasers, in craft trades. To this end it has set up test centres and consultancy offices;

(c) in SMEs the number of people working in optical technologies is set to rise by 42% by 2010, from around 36 000 to 51 000. Over 20% of companies provide initial training. The most common relevant training professions in the manufacturing field are mechatronician, industrial mechanic and high-precision optics engineer. The academically trained specialists and managers in SMEs, who to a large degree shape the evolution of optical technologies, usually satisfy their training needs through informal learning processes. These should be enhanced with practical, on-the-job, flexible, tailored training which allows them to gain additional qualifications. 21% of SMEs identified a need for continuing training in applications and procedures, 24% saw a need for schooling in basic technology and 41% expressed a desire for interdisciplinary know-how and soft-skills training. 58% of the companies also emphasised the importance of efficient networks as future platforms for knowledge transfer.

6. Conclusion and recommendations

Nanotechnology is a young, dynamic, global technology. It is not yet possible to assess precisely what the skill requirements of this field will be. In Germany the first steps towards gathering a complete picture have been taken by the BMBF. Based on findings to date, the following measures to avert a future shortage of skilled workers in the field of nanotechnology seem expedient. Some are already being implemented in Germany:

(a) for vocational training we recommend modernising and adapting existing training professions, developing additional course modules and setting up training centres – for craft trades also;
(b) for university courses we recommend devising new degree programmes, qualifications and continuing training modules (including for distance learning) and promoting interdisciplinary research groups and courses;
(c) appraising existing continuing training options and increasing transparency;
(d) enhancing stakeholder networks and strategic alliances (companies, competence centres, educational establishments, government business promotion agencies and the public sector);
(e) strengthening the appeal of technical and scientific professions for school pupils;
(f) given the growing number of older and/or unemployed academics, we must find ways of encouraging people to participate in part-time continuing training and lifelong learning. This imparts the additional knowledge people need to keep up with the changing demands of their profession, allowing us to benefit from the experience of these venerable experts and reintegrate them into the world of work.

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Part III
Networking and knowledge sharing

Alena Zukersteinova
Skillsnet: international network on early identification of skill needs

Gudrun Steeger
The FreQueNz initiative

Mark Morrison
Nanoforum: European nanotechnology gateway

Oudea Coumar
Caneus approach for development and commercialisation of micro and nanotechnologies for aerospace applications

Skillsnet: international network on early identification of skill needs

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1. Introduction

Skillsnet was set up by Cedefop at the beginning of 2004 as a response to the demand of experts, policy-makers and social partners from the field of early identification of skill needs. The network brings together highly qualified researchers and other stakeholders from across the world to present and discuss outcomes and methods of research and analysis on new and changing skill needs as well as medium to longer-term outlook for skill needs in the labour market. The network provides a forum for information exchange and generation of new activities and projects in the early identification of skill needs by bringing in a multidisciplinary cross-country perspective. It helps to increase transparency as to skill needs in various sectors and occupations across countries and builds on already existing structures in the field. The outcomes of research are actively discussed all relevant stakeholder working on the identification of skill needs with a view to their transfer into education and training policy and practice.

2. Network's objectives and target groups

The key objectives of the network are twofold: to present and to discuss results of early identification with policy-makers and practitioners with the view of their transfer to education and training and to provide a forum for researchers and experts in the field of early identification with the view of exchange of their experiences, and the increase of transparency in methods and approaches. Skillsnet aims at fostering networking, cooperation and exchanges among countries and among researchers, policy-makers, practitioners and social partners from Europe and beyond on the main trends and developments in the field of early identification of skill needs.

Skill needs in regions, specific sectors, companies and occupations are of particular interest. Similarities across territories, sectors and occupations help to identify common European or international trends in skill requirements, for example in tourism, logistics and new technologies (e.g. nanotechnology, biotechnology, fuel cells, etc.). Holistic approaches and innovative solutions have a priority in research and analysis that can cater for the time gap between the actual change in demand and the policy and implementation response. The transfer of findings into policy and the implementation of reforms are of central importance and involve again all actors – policy-makers, social partners, training organisations and researchers – to ensure the acceptance and legitimacy of reforms.

Moreover the network supports various partners in finding their common language and their respective role in the early identification process. Skillsnet tries to facilitate better communication between research and policy and also within the research itself (i.e. tries to find common language of different types of researchers). Inter-institutional and expert networking is, therefore, a well appreciated solution.

3. Skillsnet activities

Although Skillsnet operates as a voluntary forum for dialogue and information exchange, in three years has had around 180 registered members from all over the world and from different target groups. And many more participate actively in Skillsnet's work but are not formally registered via the electronic platform. Most members come from research institutes; however ministries, universities, social partners, businesses, training institutions, consultancies, policy-makers as well as various European and international institutions are also represented.

To foster cooperation and exchange of knowledge and findings Skillsnet uses the European Training Village (ETV), an interactive electronic platform on vocational education and training which is moderated by the Cedefop team (11). The platform is aimed at improving transparency, fostering exchange of both information and experts, and promoting cross-country cooperation. The network members use the electronic platform for sharing their methodological approaches and findings. The forum is also used for generation of common projects, calls for cooperation and dissemination of research results. All interested experts and stakeholders can apply there for a membership via online application form.

The Skillsnet website consists of two parts, a public domain where information is available to a broader public and a restricted area open to members only. The restricted area provides an opportunity to members to share research findings and information, to post working papers or to look for project partners. Members providing such information can signal whether they want to make this available to a wider public or a restricted audience only. All members have access to information on forthcoming events in the field of early identification of skill needs organised by Cedefop or other members of the network. Another advantage can be seen in a special section called 'Who is who in Skillsnet' which allows members to look for project partners.

Skillsnet publishes research results and proceedings from conferences and workshops with a view of their transfer into education and training policy and practice. Apart from starting to produce a newsletter, *Sector flashes* were introduced in 2005 to summarise the main trends and related skill needs in selected sectors.

4. Skillsnet's insight into selected sectors

Since 2004, Skillsnet looks into selected sectors of economy to identify the latest trends and skill needs in the sector. It investigates future skill needs but mainly the emergence of new skill needs which are not (yet) covered by related policies and statistics. This information is necessary for future-oriented policies defining and validating skills, knowledge and competences and implementing them in curricula, training regulations, qualification standards as well as using them for vocational guidance. For this purpose Skillsnet organises sector oriented workshops on a regular basis with the aim to discuss the current situation and the development potential of the particular sector focusing on the identification of future skill requirements. A background study, if available, workshop proceedings and Skillsnet *Sector flashes* are published by Cedefop after each sectoral workshop highlighting the main trends, developments and skill needs in the sector.

First sector oriented workshop took place in April 2004 in Halle, Germany and discussed trends and developments in tourism in the old and new Member States of the European Union against the background of changes taking place in North America.

Second sector oriented workshop looked at new and emerging technologies and in particular at nanotechnology. Proceedings of the workshop, which took place in July 2005 in Stuttgart, Germany are presented in this volume. Background study *Identification of skill needs in nanotechnology* and Skillsnet sector flash on nanotechnology have been published and are available on Skillsnet website in the special section devoted to skill needs in sectors.

Other sectors that have been covered or are planned to be covered by Skillsnet include innovation in agri-food and forestry-wood chains, health and social care, biotechnology, logistics, environmental sector, etc.

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The FreQ   ueNz initiative

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1. Introduction

The initiative for early identification of qualification needs was launched in 1999 by the Federal Ministry of Education and Research (BMBF). The FreQueNz research network is the essential element of this initiative (FreQueNz is the abbreviation of the German term of Network for early identification of qualification needs). This network has the task to identify new skills and to assess the significance of its findings for vocational training. 12 institutes and organisations carry out projects with a mainly qualitative focus on specific sectors of activity, firms and target groups. The research activity is linked by the network, making it possible to gain an overview of the work and to discuss methods, approaches and results while research is still in progress. The network enables an efficient dissemination of results and makes it easier for both project partners and users to contact each other and thus to communicate and cooperate. The aim of the initiative on early identification is to identify skill needs, to make findings rapidly available and to formulate options for action in the fields of initial and continuing training.

In parallel with these activities, the FreQueNz network has established an intensive cooperation with the European network on early identification of skill needs (Skillsnet). Methods, approaches and results have been exchanged and this workshop was an excellent example of such exchange and interchange. Two large-scale conferences organised by Cedefop, BMBF, Fraunhofer IAO and the Social Science Research Center Berlin have already taken place.

2. Importance of early identification of skill needs

From the point of view of the BMBF, the early identification of skills needs is a necessary exercise to avoid an imbalance of skills and shortages of skilled workers on the labour market. New skills indicate a continuous alignment of vocational training. All this has highlighted the need to update the regulations governing initial and continuing training and to define new occupations and skill profiles. In 1999, the German government and the social partners agreed to launch a skills offensive with a focus devoted to the early identification of skills and qualification needs.

On the basis of this agreement, the BMBF promotes the 'Initiative for Early Identification of Qualification Needs' with its nationwide network, which embraces various research institutes and vocational training institutions and bodies. One of the tasks of this network is to identify future-oriented skill profiles and to devise ways and means of establishing new occupational categories and bringing existing ones up to date. Thereby the network contributes towards modernising the vocational training system and hence towards meeting the challenges outlined above.

In particular, early identification projects applying mainly qualitative analytical methods to branches of industry, firms and target groups will make it possible to avoid imbalances between the demand for and the availability of qualifications and skills, and to ensure that skill profiles are in line with future demands. Furthermore, it is necessary to transfer the findings to the specific target groups. That is the reason why, besides its analytical studies, the initiative develops ways to transfer the results to different groups, for example employees, employers, training institutions and employment agencies. Moreover, the communication of transparent results to organisations and interested individuals is a suitable instrument to influence skill-related decisions in a manner designed to reduce skill imbalances.

3. Activities, projects and future plans

The BMBF sponsors a variety of projects with different objectives. The FreQueNz network combines research institutions and educational organisations as well as social partners. At the start of the initiative, the emphasis was on evolving, testing and evaluating a variety of methodological approaches towards early identification. Now that the appropriate methods have been decided upon, work is in progress to identify new skills and qualification needs in a wide variety of fields of activity and to disseminate the results to an interested (specialist) public. In 2004 and 2005, the BMBF, together with FreQueNz, has started a process to intensify the transfer of results and to evaluate the findings. At the end of this process, the BMBF and the social partners organised a conference in Berlin in April 2005.

Currently, the BMBF plans to sharpen the profile of the initiative on the basis of the conference results. The BMBF will start a new dialogue between science, the social partners, training bodies and enterprises. This dialogue is intended to find a common ground to develop long-term cooperation between all players. We hope to achieve an information platform which is able to cluster and to evaluate further information of economic developments in addition to the FreQueNz results.

Furthermore, the BMBF plans a study to create a methodological framework for research. The aim of this framework is to offer effective ways to identify new skills in the context of specific problems. The project also goes even further than these activities.

Meanwhile, studies of new skill needs have been conducted in several branches of industry, such as building and construction, the motor vehicle industry, the electronics industry, financial services, health and wellness, information and communications technology and, last but not least, in emerging technologies.

The reason for sponsoring projects in the field of emerging technologies is obvious. One of the most important factors that contribute to shape a region's economic development and thus to create a nanotechnology-driven industry in Germany is not only the presence of a capable scientific and economic community but also the availability of qualified workers at all levels.

The BMBF has also initiated several activities which aim at modernising and strengthening the education and professional training systems, and enhancing Germany's appeal to young scientists. These activities include post-graduate scholarships, the BioFuture programme, the creation of junior professorships, the university future initiative (ZIH) and the efforts to introduce internationally recognised academic degrees (bachelor and master).

Thus, education is the key to the future nanotechnology job market and this is the reason why the BMBF supports studies to identify new skills as well as to create specific courses or training programmes.

To promote the information transfer the FreQueNz network has organised several conferences and published research results in the form of newsletters and books in the series *Qualifikationen erkennen – Berufe gestalten* (recognising skills – structuring occupations). A website has also been created at which all the results of individual research projects are available ([12]).

([12]) Available from Internet: http://www.frequenz.net/ [cited 6.9.2007].

Nanoforum: European nanotechnology gateway

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1. Introduction

Nanoforum is a pan-European nanotechnology information network funded by the EU. The primary source of information is the website (www.nanoforum.org), where both the public and the R&D community can access information on nanosciences and nanotechnologies. Nanoforum also publishes its own timely reports on key market sectors and the economical and societal impacts of nanotechnology and organises events throughout the EU to inform, network and support European expertise.

2. About the network

The Nanoforum network started in July 2002 and is led by the Institute of Nanotechnology (the UK) with partners including VDI-TZ (Germany), CEA-Leti (France), MTV (the Netherlands), METU (Turkey), Unipress (Poland), the Monte Carlo Group (Bulgaria), FFG (Austria), and NanoNed (the Netherlands). Nanoforum provides information and support to the European nanotechnology community. It is currently funded until July 2006.

Nanoforum actively participates in training and education activities through:

(a) provision of information on its website: education courses; job advertisements; collaboration boards (where individuals can post requests for student training, exchange visits, partners in project applications, etc.);

(b) reports (including *Outcome of the open consultation on the European strategy for nanotechnology*, *European nanotechnology education catalogue* and *European nanotechnology infrastructure and networks*);

(c) events such as summer schools and career information days for graduate level students.

This short article describes these activities and the interested reader is encouraged to visit the Nanoforum website for further information.

3. The Nanoforum website

The Nanoforum website has specific sections with links to education and training courses (both residential and online), jobs, articles and reports (including those published by the Nanoforum consortium itself. This provides the user (whether they are a school pupil, scientist, business person or someone with no background in sciences) with an introduction to nanosciences and nanotechnologies, and links to the variety of options available for further learning.

All information on the Nanoforum website is categorised by scientific field (e.g. chemistry and materials, health and medicine) allowing users to quickly find what they are looking for. Currently there is a database of over 1 600 news items, 1 500 organisations and almost 300 publications.

4. Nanoforum reports

Between August and October 2004 Nanoforum hosted an online survey, in cooperation with the European Commission, to determine the community's attitude towards all aspects of nanoscience and nanotechnology development.

A total of 749 people responded (93% from 32 European States), which made it one of the largest of its kind in Europe. The survey attracted responses from not only the R&D community, but also included journalists, lecturers and the business community. The survey canvassed opinion on the impact of nanoscience and nanotechnology, the relative standing of Europe compared to other world regions, funding and infrastructure, societal concerns, and health and safety. Most people agreed that there should be an integrated and responsible approach to nanoscience and nanotechnology development.

The survey revealed some common attitudes, namely that:

(a) nanotechnology will have a strong impact on European industry (90%) and its citizens (80%) within 10 years;

(b) Europe is perceived to be far behind the US in both nanoscience (76%) and the transfer of nanotechnology to industry (77%);

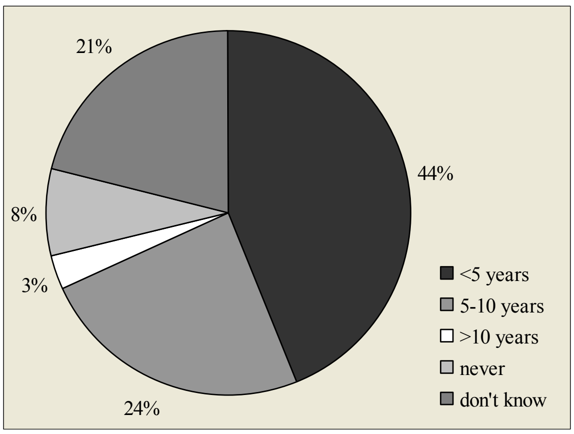
(c) chemistry and materials, information and communications technologies, and healthcare are the key areas in which nanotechnologies will have an impact;

(d) there should be a significant increase in research funding via the framework programme (79%);

(e) there is a lack of European infrastructure, with 64% supporting the creation of new facilities at European level in, for example, nanomedicine, nanomaterials and information technologies;

(f) Europe may face a shortage of skilled research personnel for nanoscience and nanotechnology in 5-10 years (68%) (Figure 1) and there is a need for interdisciplinary skills (90%);

Figure 1: Survey response to the question
'will there be a shortage of nanoscientists and technologists?'



(g) further training opportunities and mobility for researchers are seen as important (80%);

(h) health, safety and environmental risks should be integrated early into research (75%) and there is need to address knowledge gaps about free nanoparticles (72%);

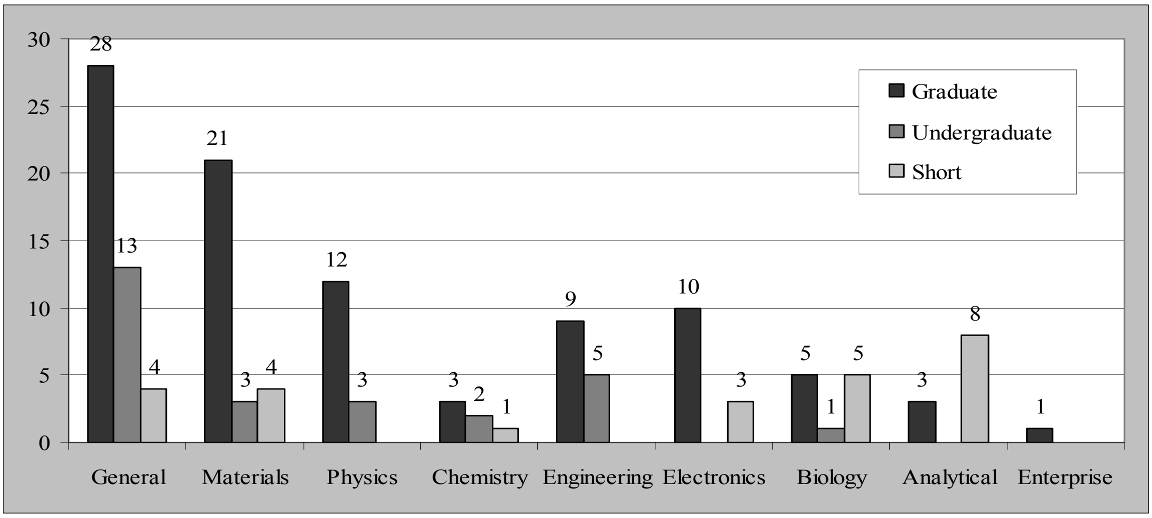
(i) Europe should take account of the societal impact of nanotechnology from an early stage (75%) and that more communication and dialogue is needed;

(j) cooperation with developed (96%) and less developed (76%) countries is important and an international 'code of good conduct' would be welcomed (87%).

Other specific comments included: web-based learning and training should be made available; there should be more summer schools or short residential courses for practical training; more emphasis on ethics during training; the creation of EU institutions for training, centres of excellence and sharing of best practices. Importantly, only 9 respondents saw no need for specific nanotechnology education.

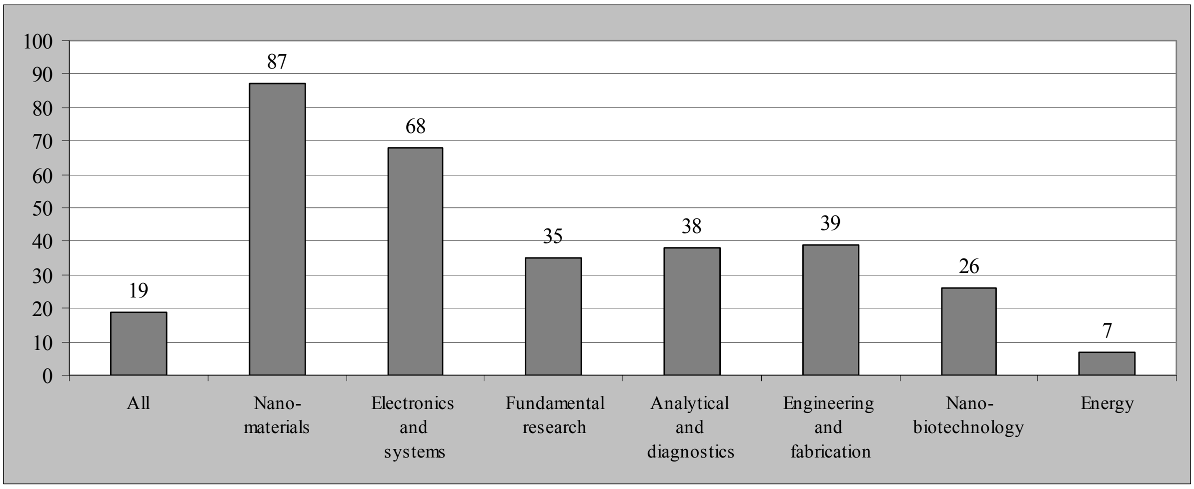
In March 2005 Nanoforum published a *European nanotechnology education catalogue*. This lists 144 courses across the EU and associated countries. Of these courses 91 were at the graduate level, 28 at the undergraduate level and 25 were summers schools or course of up to a few weeks duration. Figure 2 shows the breakdown of courses by discipline. Graduate level courses are available in a wide variety of subjects including materials, electronics, nanobiotechnology, chemistry and physics (25 have been classed as general because they provide education and training in several different disciplines). Undergraduate courses are also available in different disciplines (although most are general or focussed on materials, chemistry, physics or engineering). Interestingly, analytical topics and nanobiotechnology are offered most often as short training courses. The majority of these courses are found in the UK, Germany and France, however Denmark offers a large number of short training courses through the iNano Centre at the University of Aarhus.

Figure 2: European nanoscience and nanotechnology courses by scientific field



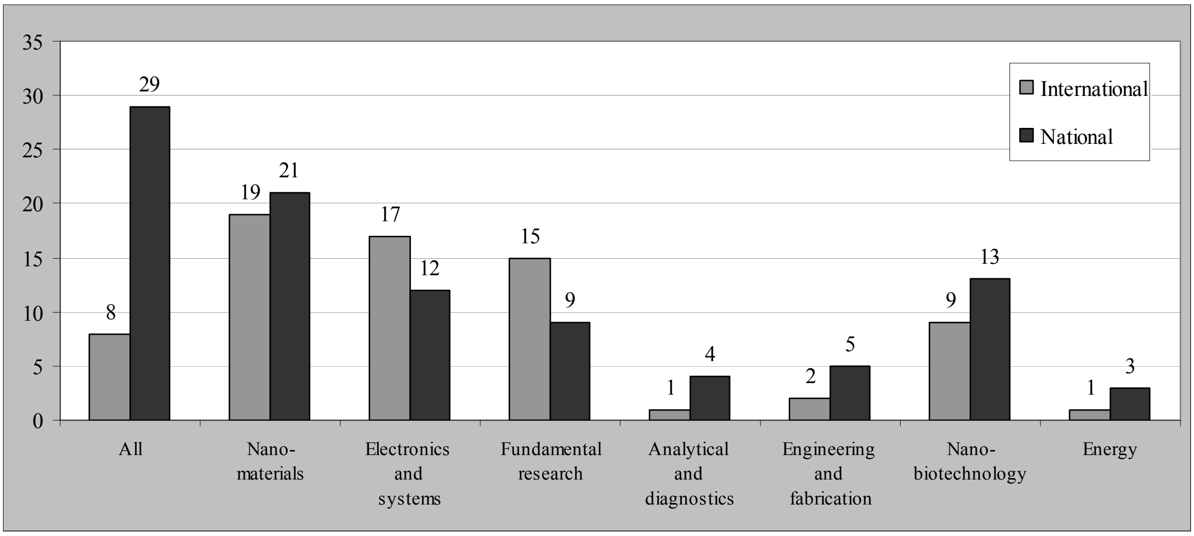
The report *European nanotechnology infrastructure and networks* describes 16 major centres of infrastructure and 224 other centres throughout Europe, all of which are open to external users for collaboration, use of equipment, or provision of services. The report details the disciplines and technology sectors that each centre specialises in along with facilities that are available (Figure 3). Facilities offering R&D infrastructure for nanomaterials, electronics and systems are the most common (87 and 68 centres respectively), with fundamental research (primarily physics and chemistry) being a major activity of 35 centres. Analytical and diagnostic facilities are offered in 38 centres, and engineering and fabrication in 39. In contrast nanobiotechnology facilities are only available in 26 centres, and only 7 operate in the field of energy. While many centres had strengths in more than one sector, 19 centres covered multiple or all sectors.

Figure 3: Nanosciences and nanotechnologies infrastructure in the EU and associated states (by area)



The report also describes 143 European networks which offer support for collaboration and information exchange between members (Figure 4). Of these, 79 are national networks with the remaining 64 involved in international cooperation. Of all nanoscience and nanotechnology networks in the EU and associated countries, 37 (or 25.9%) cover all disciplines. The most common type of thematic network focuses on nanomaterials (40 or 28%). This is followed by electronics (29 or 20.3%), fundamental research (mainly physics and chemistry) by 24 networks (16.8%), nanobiotechnology (22 or 15.4%), engineering and fabrication (7 or 4.9%), analytical and diagnostic tools (5 or 3.5%), and energy (4 or 2.8%).

Figure4: Comparison of international and national networks based on area covered



International networks tend to be more specialised (36.7% of national networks support all disciplines compared with 12.5% of international networks). However, in two areas (analytical and diagnostics, and energy) most of the relevant networks are national. Of the national networks most (22) are coordinated from Germany, with 9 from the UK, and 4 from each of France, the Netherlands, and Poland.

5. Nanoforum events

To date, Nanoforum has organised two summer schools and two career information days for graduate level students. The first summer school took place in les Houches in France and was attended by 59 students (22 from outside France). This included lectures and practical sessions on solid-state physics, nanomechanics, molecular machines, molecular assembly and biomolecular topics. The second summer school entitled ‘Molecular self-assembly: biomimetics as a route to novel products and processes’ was held in Cambridge and attended by 29 delegates from 13 different European countries, and from academia, industry and government agencies. This covered topics from physical to life sciences, with two practical sessions at the Cambridge Nanoscience Centre. The information days (one in France and one in the UK) have afforded graduate level students the opportunity to learn more about career options not only in academic R&D, but also in industry and business.

6. Conclusion

The Nanoforum consortium provides several information services to individuals who wish to learn more about nanoscience and nanotechnology in general or those who require specific assistance or training. Details of all these activities including reports and PDFs of the presentations from many of the speakers at Nanoforum events are available for free download from the Nanoforum website.

Caneus approach for development and commercialisation of micro and nanotechnologies for aerospace applications

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1. Introduction

This paper highlights the current state of art of micro and nanotechnologies (MNT) and also describes the Caneus approach for the development and commercialisation of MNT for aerospace applications. The development of advanced micro- and nano- electro mechanical systems (MEMS and NEMS) technologies for space applications faces a similar dilemma in successfully 'maturing' new concepts. The space agencies (NASA, ESA) measures a means of evaluating the maturity of technologies, known as the technology readiness level (TRL) scale, that has now found widespread use in industry. For the end-user, reliability assurance is an integral part of the space qualification process, by conducting flight experiences, we could qualify quickly the emerging technologies like MNT for space industry.

2. Background

The explosion in MEMS and NEMS has occurred primarily within academic and research institutions. These institutions have concentrated for the most part on demonstrating the proof-of-principle for novel MEMS/NEMS devices. The silicon integrated circuit technology is the initial enabler for MEMS, the initial top-down lithographic fabrication approach has been augmented with a bottom-up self assembly approach. The bottom-up approach has been effective in NEMS, to bridge the gap between atomic dimensions and the limits of high-resolution lithography techniques. Since the past decade, ink-jet print-head, micro-sensors and micro-actuators based on silicon and other technologies have been developed rapidly. In many of these instances, the successful transition occurred either as a result of the initial development being undertaken by the in-house research department within a company, and followed by transfer to the manufacturing division or as a result of a successful partnership between a company and an external institutions. The smart sensors, realised with MEMS, have already proven their great interest in the fields of applications such as automotive, medicine, geophysics.

Nanotechnology – in its various forms such as nanoelectronics, nanoelectromechanical systems, ultra small and highly sensitive sensors, multifunctional materials, biologically inspired materials, systems and architectures, and possibly many others scientists have not yet thought of – is expected to play a strong and critical role in future space transportation and exploration.

Since these technologies offer great advantages in terms of reduction of mass and on board power, it should be interesting to apply them in the space domain to increase performance and probably to lower overall costs of existing space programmes and also develop new concept space missions.

The ideal solution developed to overcome the TRL-gap problem has been to fly MEMS/NEMS devices at the low and mid TRL stage development. Flight demonstrations are a key issue since new technologies like MNT not qualified in-orbit are usually seen as risky and are discarded by the space industry.

3. State of development of MNT

3.1. Micro systems technology/MEMS

The microsystems technologies have become a key technology with an astonishing innovation potential for many industrial sectors as well as for emerging technologies in the world. The integration of numerous materials and functions and the trend towards miniaturisation have been a powerful factor for development of new innovation fields within the automotive, the chemical, life science and aerospace fields.

The key features of MEMS are the miniature mechanical systems with micron feature size, batch fabricated with no assembly required and exploits microelectronics infrastructure for common technology base for sensors, actuators and electronics. The MEMS are not only making things small but also the microelectronics revolution changed the world because of cost, not size. The MEMS offers a way to make complex electromechanical systems at low cost. The cost and the performances must be the driver to fully realise the potential benefits of MEMS. The cost issues are favourable due to: maintaining batch fabrication, using IC standard materials and leverage 'standard' technologies and processes. Micro sensors are miniature devices that convert information about the environment into electrical form that can be read by instruments. Sensors are increasingly used as computer input devices as computing power increases and become less expensive. Sensors thus function as the eyes, ears, nose, and touch for the computer, making it aware of its environment.

3.2. Nanotechnology

Nanotechnology is the creation of useful, functional materials, devices, and systems through controlling and manipulating matter on the nanometre-length scale (1-100 nm), and exploiting novel phenomena and properties (physical, chemical, biological, mechanical, electrical) at that length scale.

The prefix nano means a billionth – a nanosecond is one billionth of a second, a nanometre is one billionth of a meter, and so on. For comparison, the head of a pin measures one million nanometres across. A red blood cell has a diameter in the range of thousands of nanometres. Ten nanometres is 1 000 times smaller than the diameter of a human hair. DNA molecules are about 2.5 nm wide. An individual atom measures a few 10ths of a nanometre in diameter.

Useful applications for nanotechnology exist in areas as diverse as materials, manufacturing, bio-medical, electronics, computing and transportation. Nanostructured metals and ceramics, for example, could be made into exact shapes without machining. Abrasives, coatings, paints, and composites all could be made stronger and better using nanoparticles. Integrated nanosensors would enable massive amounts of data to be acquired, processed, and shared with minimal size, weight, and power consumption. Less expensive remote and in-vivo devices would provide new routes for drug delivery. More durable, rejection-resistant artificial tissues and organs could be created. And in automobiles, nanotechnology can lead to wear-resistant tires, improved battery technology, and lightweight composites for increasing fuel efficiency. The NASA Ames computational nanotechnology researchers have designed a carbon-nanotube based nanogear shown in Figure 6.

The world research focus, summarised in Table 1, covers a wide range of subjects: carbon nanotube synthesis, characterisation, functionalisation, electrode fabrication sensor development, application of carbon nanotube in atomic force microscopy, inorganic nanowires for sensor and detectors, protein nanotubes, nanotechnology in genomics, development of quantum device simulator, computational optoelectronics, atomic chain electronics, and bacteriorhodapsin based holographic data storage.

Figure 6: Carbon-nanotube based nanogear with benzyne molecules bonded as teeth

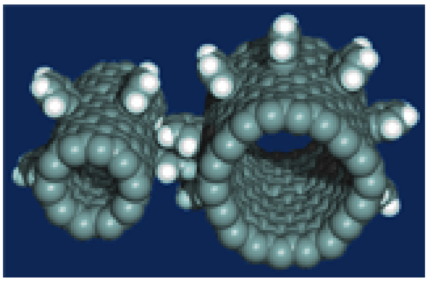


Table 1: World nanotechnology research focus

Research Focus	

Carbon Nanotubes:
• growth (chemical vapour deposition and plasma enhanced chemical vapour deposition)
• characterisation
• atomic force microscopy tips
  ◦ metrology
  ◦ imaging of mars analog
  ◦ imaging bio samples
• electrode development
• biosensor (cancer diagnostics)
• chemical sensor
• logic circuits
• chemical functionalisation
• gas absorption
• device fabrication
Molecular electronics:
• synthesis of organic molecules
• characterisation
• device fabrication
Inorganic nanowires
Protein nanotubes:
• synthesis
• purification
• application development
	Genomics:
	• nanopores in gene sequencing
	• genechips development
	Computational nanotechnology:
	• carbon nanotubes – mechanical, thermal properties
	• carbon nanotubes – electronic properties
	• carbon-nanotube based devices: physics, design
	• carbon-nanotube based composites, BN nanotubes
	• carbon-nanotube based sensors
	• DNA transport
	• transport in nanopores
	• nanowires: transport, thermoelectric effect
	• transport: molecular electronics
	• protein nanotube chemistry
	Quantum computing
	Computational quantum electronics
	• noneq. green's function based device simulator
	Computational optoelectronics
	Computational process modelling

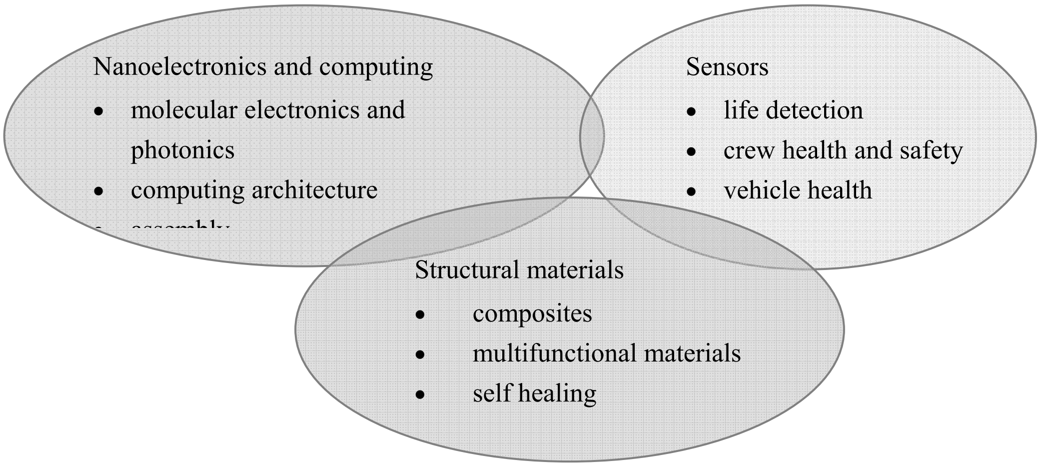
4. Why nanotechnology for space?

The world-wide boom in nanotechnology funding and far reaching innovation pushed the space community to screen the applicable specific nanotechnology. The NASA has established a nanotechnology roadmap to be reached up to 20 years in the future. Here are the positive arguments for nanotechnology space applications.

Advanced miniaturisation is a key thrust area to enable new science and exploration missions: ultra small sensors, power sources, communication, navigation, and propulsion systems with very low mass, volume and power consumption are needed.

Revolutions in electronics and computing will allow reconfigurable, autonomous, 'thinking' spacecraft.

Figure 2: Nanotechnology major sectors



Nanotechnology presents a whole new spectrum of opportunities to build device components and systems for entirely new space architectures: networks of ultra small probes on planetary surfaces, micro-rovers that drive, hop, fly, and burrow and collection of micro spacecraft making a variety of measurements.

New radiation shields: research in new protecting shields for space missions, identify shielding principles (radiation interaction mechanisms, choice of material) and test shielding effectiveness (particles, energy spectrum).

As illustrated in Figure 2, for space domain, we should work on three major sectors like nanoelectronics and computing, sensors and structural materials. Revolutions in electronics and computing will allow reconfigurable, autonomous, 'thinking' spacecraft.

5. Technology readiness level definitions

However, applying MNT in the space domain needs validation of these devices under space launchers environment. The development of advanced MEMS/NEMS technologies for space applications faces a similar dilemma in successfully 'maturing' new concepts. The space agencies (NASA, ESA) measures a means of evaluating the maturity of technologies, known as the TRL scale, that has now found widespread use in industry. The TRL scale ranges from levels 1 through 9, with levels 1-3 being at the so-called low-TRL, basic research into demonstrating the proof-of-concept, while levels 4-6 correspond to mid-TRL development, which is the reliable demonstration of subsystems based on the new technologies, and finally, levels 7-9, high-TRL, correspond to successful utilisation of these subsystems in space missions. The TRLs are presented in Figure 3 and in Table 2.

Figure 3: Technology readiness levels

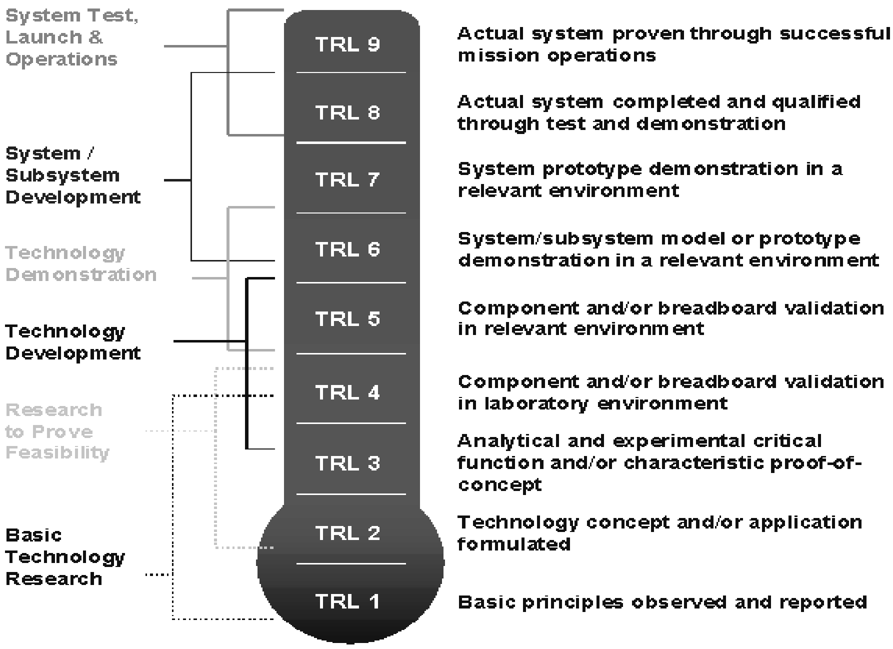


Table 2: Technology readiness levels

Technology readiness level	Description
Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins with to be translated into applied research and development. Example might include paper studies of a technology basic properties.
Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
Analytical and experimental critical function and/or characteristic	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively 'low fidelity' compared to the eventual system. Examples include integration of ad hoc hardware in a laboratory.
Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in the demonstrated readiness of a technology. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
System prototype demonstration in a operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.

Actual system completed and 'flight qualified' through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
Actual system 'flight proven' through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last 'bug fixing' aspects of true system development. Examples include using the system under operational mission conditions.

6. MNT needs for space systems

For today's space transport vehicles, the miniaturisation is not prerequisite, since the propulsion function drives their overall volume and architecture, and there are places enough for electrical devices and equipment. But for payloads (satellites, probes, re-entry vehicles) and future re-usable launch vehicles, the mass and the volume are the major constraints, hence miniaturisation becomes very interesting. It should interfere on the launcher by reducing its performance needs so as to change the launchers performance requirements. There are rooms of interest to use MNT for space transportation vehicles.

As a consequence, we have to reconsider, at least partially, the architecture of some electrical sub systems and structures to get the real benefit of using MNT for short term (≤ 5 years). MNT can procure some advantages like reduction of global cost with better reliability. And also, it allows in the future using the up to date technologies and devices available in the market for our space equipments and systems.

Today, nanotechnology is really in low TRL 1-3, but it presents a whole new spectrum of opportunities to build device components and systems for entirely new and bold space architectures such as 'thinking' launcher.

7. Caneus network

Caneus is an international community of expertise that can scan for and recognise real opportunities in Canada, Europe, Japan and the US; it can package concepts and market them to end users in each of these regions; and it can deliver polished end products and processes –all rapidly and low cost. This will help Caneus close the TRL gap for aerospace MNT development.

Began as a CANadian, EUropean and USa initiative, now includes Japan and South Korea.

7.1. History of Caneus

Since its inception in 1999, Caneus has rapidly grown to be the world's premier professional organisation with the charter to rapidly and cost-effectively transition emerging MNT to aerospace and other applications:

(a) 1999: Canada-CLS3 initiated and lead the international consortium on MEMS/NEMS for aerospace applications;
(b) 2001: Canada-CLS3 initiated and organised the first international workshop on MEMS for aerospace applications with representation from NASA, DARPA, EU and

formulating an effective and efficient framework for coordinated North America and Europe on development of MNT for aerospace applications;

(c) 2002: Canada-CLS3 staged the Caneus 2002 workshop in Montreal, Canada, with the participation of 108 speakers including 2 Nobel Laureates representing 14 countries, international cooperation agreement covering nanotechnology and space was developed;

(d) 2003: Caneus USA Inc. was founded and together with the AIAA and NASA. Caneus developed the framework for MNT prototypes and programmes for discussion at Caneus 2004 conference;

(e) 2004: Caneus Organisation initiated a worldwide survey of potential MNT pilot project concept topics, organisation of Caneus 2004 conference on November in Monterrey, USA;

(f) 2006: Caneus 2006 conference at Toulouse, France;

(g) 2008: Caneus 2008 conference in Japan.

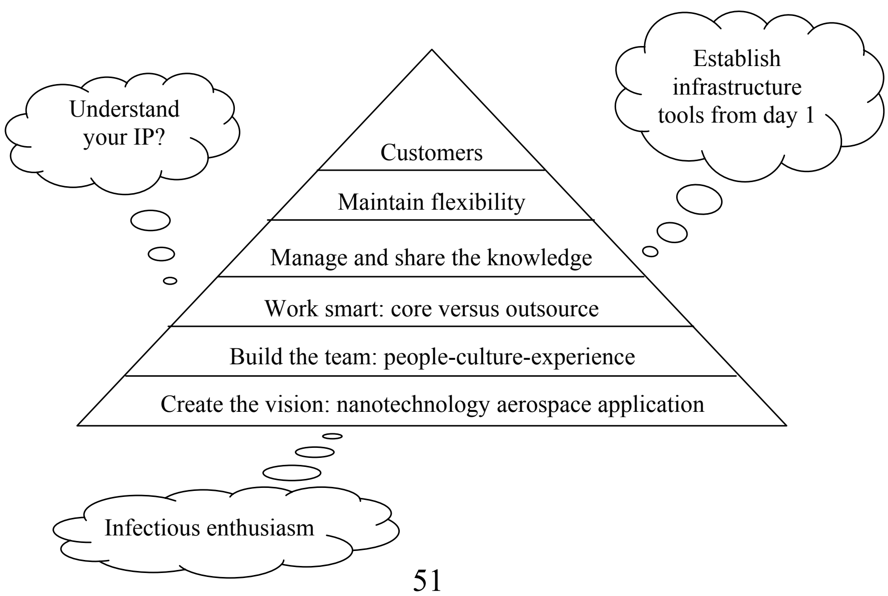
An important information exchange and dissemination forum for the Caneus organisation is its bi-annual, international conference. The most recent Caneus 2004 conference in Monterey, California attracted over 250 world-class speakers and attendees from across Canada, the US, Europe, Japan and South Korea. Represented at the conferences were the advanced MNT research and development, system development and reliability testing, aerospace and defence applications, and the private and public investment communities. Participants included representatives from leading academic research institutions such as UCLA, TU-Delft and Tohoku University, aerospace companies such as Boeing Corp. and EADS (Airbus, ST, CRC), space agencies such as NASA, ESA, CNES and JAXA, and government organisations such the US State Department and the European Commission.

7.2. Caneus 6-step method

The end users are an integral part of process for prototype development (Figure 4):

1. find and recognise proven concepts;
2. develop commercialisation frameworks;
3. develop business plans for 'winners';
4. incubate start-up firms;
5. facilitate prototype development;
6. foster move to sustainable manufacturing.

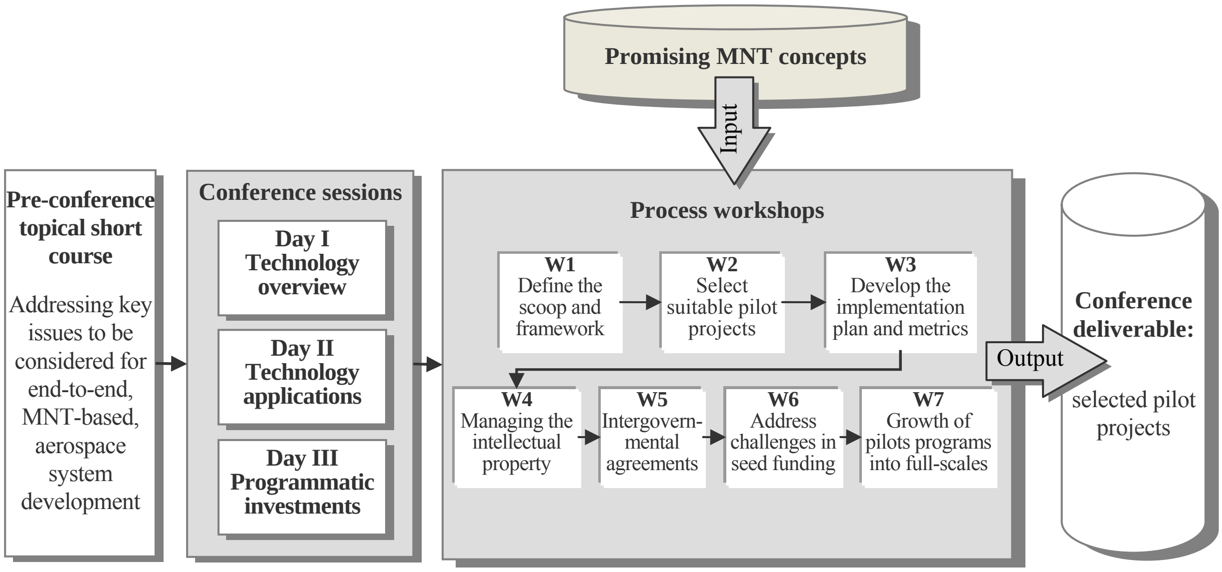
Figure 4: Caneus 6-step prototype development



7.3. Caneus conferences

Caneus host biennial conferences (2002, 04, 06) that are fully integrated into its technology transition pipeline. This international assembly of experts will analize concepts presented for further development in concert with end users to apply a true market test to the proceedings. The conference structure is given in Figure 5.

Figure 5: Caneus conference structure



8. Conclusions

In this paper we presented the state of art of MNT for space applications and also the network Caneus. Caneus attempts to achieve this challenging objective by creating a smoothly functioning, end-to-end technology development 'pipeline' that addresses all of the important aspects of the concepts-to-systems process such as prototype development, reliability demonstrations and infusion into applications. The core operating principle of Caneus is that such a technology development pipeline is possible only by fostering international collaborations that bring together complementary core-competencies from member nations. The benefit of these experiences can promote further applications on all space systems (satellites, probes, re-usable launchers and re-entry vehicles).

Today, nanotechnology is really in low TRL 1-3, but it presents a whole new spectrum of opportunities to build device components and systems for entirely new and bold space architectures such as 'thinking' spacecraft and launcher.

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Part IV:
Summaries and conclusions

Henriette Freikamp, Uwe Schumann
Nanotechnology and its effects on skill needs and occupational profiles: report of working group discussion and results

Bernd Dworschak
Skill shortages and gaps in emerging technologies: report of working group discussion and results

Liene Ozolina, Alena Zukersteinova
New skill needs in nanotechnology Summary and conclusions

Nanotechnology and its effects on skill needs and occupational profiles: report of working group discussion and results

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1. Introduction

Participants of this working group discussed examples, experiences and visions of nanotechnology and its effects on skill needs and occupational profiles. The discussion was introduced by two contributions of Jan Voves and Grit Petzoldt-Gühne. Jan Voves from the Czech Technical University Prague presented experiences on nanotechnology and skill needs of the Czech Republic. Grit Petzoldt-Gühne from Schott Germany, a nano optics company, described a special method for the identification of qualification needs and human resources development within the company.

Within the following working group discussion, the participants answered three main questions regarding: the trends of nanotechnology; the effects of these trends on skill needs and occupational profiles; the conclusions.

The present article includes summaries of the two contributions as well as the results of working group discussion.

2. Contributions summaries

Jan Voves stated some trends and skill needs in the field of nanotechnology as well as the state of affairs in the Czech Republic in the European context. Going out from the trend description of nanomaterials, nanobiotechnology and nanoelectronics, Jan Voves presented impacts on public health, safety and environmental protection. Afterwards the impact on jobs, education and training was stated. Nanotechnology, Jan Voves said, is a boom time for jobs for science and engineering workforce. In addition there is a need for supporting laboratory services, sales, clerical and office work. In proportion to the expected penetration of nanotechnology into several sectors of industry, the current number of employees with the required skills is far too limited. There will be a need for development of nanotechnology education and training. Because of the interdisciplinary nature of nanotechnological work, a new generation of scientists, engineers and technicians is needed with broad knowledge of physics, chemistry, biology and engineering as well as of the basic principles of manufacturing and control. Specialists need to be able to work together, developing a common language and modes of interaction (teamwork and communication). After description of education and training requirements, Jan Voves presented nanotechnology research and education in the Czech Republic like the National Research Programme 2004 to 2009 with the key research direction ‘nanotechnologies and nanomaterials’, the Centre Nanotech CTU, the Czech Society of new materials and technologies and others.

Grit Petzoldt-Gühne described the practical requirements of a nanooptics company regarding the skills of employees. The Schott AG requires highly qualified personnel regarding the professional as well as the social level. They have to be mobile as well as flexible. Additional the employees need languages and other international oriented skills. At the company, employees go through a permanent monitoring of their qualification gaps by using a qualification matrix. To close early diagnosed qualification gaps, individual qualification plans are developed. Furthermore, the employees realise job rotation to promote flexibility and teamwork. They get language training, are learning in learning groups and are coached by a self management development process.

3. Results of the working group discussion

3.1. What are the trends in nanotechnology? Why do we believe nanotechnology growth?

Working group participants do expect high growth rates for nanotechnology applications in general. Huge expectations on better nanoproducts like ‘faster, smaller, cheaper’ were stated. During the fast progress in research and development broad application fields as well as application combinations of nanotechnological products occur. The most important sectors effected by nanotechnology are information and communication techniques (ICT) as well as medicine and health sector. But many other sectors or industries will be affected too, such as automotive, electronics, optics, life sciences, environment, intelligent devices, etc.

3.2. How do these trends affect skill needs and occupational profiles?

The discussion focused on the university level. Working-group participants proposed a focus change on below university level within 3 to 5 years. Beside the obligatory professional competences, employees do need several important soft skills in addition. First of all they have to work interdisciplinary. Within a team of different specialists they need to speak a common language. Teamwork and communication, especially English language, are important. Further, intercultural skills, self management, analytical and critical thinking are required.

Working-group participants discussed the way and place for education and training of the required skills. Nanotechnology is not simply a reduction of existing technologies because it starts out from other working principles and models as traditional technologies including the microtechnologies. The application of quantum effects and of processes of self organisation is characteristic for these models particularly. Nanotechnological qualifications must pick up this change of paradigms according to tendency and transfer them in production of the relevant application forms. Because of this change of paradigms the first places for learning as well as for the stimulation of future interests for intellectual challenges of science, research, observation, analysis, interpretation, abstraction and prediction are primary and secondary school.

Employees should learn the required skills at the workplace, for example by informal learning in teams or learning groups, by job rotation, working and training abroad or learning by problem solving. Teaching has to accomplish a shift from traditional instruction to constructivistic ways of learning in working situations.

3.3. Conclusions

Nanotechnology affects economy, education and the whole society. The working-group participants stated open questions, research lacks and challenges for the future. Required are:

(a) research on skill needs below university level;
(b) early dialog structures with the public on explanation, information and communication;
(c) development and test of new education and training approaches, starting at school level;
(d) research on general risks of nanotechnology, for example regarding medical, environmental, legal, ethical questions;
(e) research on social impacts of nanotechnology;
(f) research on net effects of a nanotechnological development (job boom, growing industries, etc.).

Skill shortages and gaps in emerging technologies: report of working group discussion and results

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1. Introduction

The questions at the outset of the working group discussion focused on three main areas:

(a) How can we identify future skill shortages and gaps in emerging technologies?

(b) What are specific shortages and gaps already identified/estimated for the nanotechnology sector? What are typical skill shortages and gaps experienced by other newly emerging and fast developing technology sectors? What can the nanotechnology sector learn from these experiences?

(c) How can skill shortages/skill gaps be tackled and possibly prevented?

The working group dealt with different solutions for different levels (enterprises, education and training institutions and systems, etc.) of the nanotechnology sector as well as experiences from other technological fields and sectors. Emerging technologies – and nanotechnology is a good example – often initiate high growth for particular sectors and new jobs at different occupational levels (e.g. jobs for researchers and scientists but also for a range of technicians and specialists with secondary, post-secondary and non-university tertiary education). Moreover, the whole area of new technologies demands a set of basic skills which can be specific or general at different occupational levels and which can promote innovation, research and development (e.g. innovation management). Particular skill gaps and skill shortages may significantly diminish the growth potential and other positive effects of the new technological field. The industrial utilisation of the nanometre dimension has just started. Similar to information technology, the study of the basic physics goes hand in hand with the development and the introduction on the market of first products. Furthermore, the future competitiveness of the products of many other important industries, such as the chemical, pharmaceutical, automobile, information technology or optical industries, also depends on the development of nanotechnology. Future progress in nanotechnology is decisive for the further development of these industries.

2. Results of the working group discussion

2.1. How can we identify future skill shortages and gaps in emerging technologies?

Nanotechnology is increasingly considered to be the future technology. Given this situation, the identification of skill shortages and gaps in an emerging technology such as nanotechnology is of great importance for the competitiveness of European countries and companies. This identification does not only include quantitative aspects of possible future skill shortages (how many employees are needed?). According to the maturity of a technology, this identification to an even greater extent has to include qualitative issues of skills needed for the application of the new technology (what do these employees have to know/have to be able to do?). If a technology is not very mature, and because of this is a real 'emerging' technology, profound information and knowledge on how the jobs and tasks of employees in this sector do change is needed before a solid quantitative assessment of the employment potential is possible and feasible. Against this background, the workshop discussion dealt with different ideas such as regular surveys and interviews with scientists and employers on technological developments and related skill needs, or the establishment of an EU-wide technology monitoring system. To capture new occupational profiles and skill combinations it seems necessary to collect data or to establish databases what, though, requires considerable financial resources and raises the question of useful data formats. Tackling the qualitative side of the problem of the identification of new occupational profiles, the workshop discussed the appropriate and suitable level of research. In conclusion, it might be most valuable to have a look at real on-the-job developments in (key) companies, workplaces and work processes. Employees in emerging technologies are obviously 'doing something else', they are doing things in another way than the tasks in neighbouring sectors are performed. If a technology has already arrived at the stage of product development, it might be useful to have a close look at the products themselves and to compare them with already existing products. This raises questions on the skills needed to maintain these products (what do employees have to know to maintain the product? Which skills are needed to maintain the product?). All in all, the identification of the 'stage' of an emerging technology seems to be a central challenge to identify new skill needs by systematic research such as the analysis of prototypes, technical systems, products, and natural as well as scientific principles. Another challenge – in the case of nanotechnology – is its multidisciplinary character which necessitates to identify new skill needs across disciplinary borders.

2.2. What are specific shortages and gaps already identified/estimated for the nanotechnology sector? What are typical skill shortages and gaps experienced by other newly emerging and fast developing technology sectors? What can the nanotechnology sector learn from these experiences or other technologies?

Similar to information technology, in nanotechnology the study of the basic physics goes hand in hand with the development and the introduction of first products on the market. The concept of technology readiness levels (TRL), which has been presented at the workshop, might be a basis for a comparison with existing products and the derivation of new skills needed along the line of product development at different stages (Coumar; in Part III).

Skill shortages in emerging technologies usually reflect the fact that neither existing work practices nor the official occupational nomenclature acknowledge their existence. In some sectors, Europe already shows a lack of specialists (microtechnology, chemistry, etc.) and a typical gap experienced by other technologies is the insufficient supply of basic natural sciences knowledge. Other useful skills include entrepreneurship skills, trans-sectoral skills, recycling, quality management, work safety and health issues (risk management). Innovation management and cross-disciplinary communication seem to be the major skill gaps. However, a consequent assessment of chances but also of risks of nanotechnology with regard to markets, environment and society would decrease the respective knowledge gap of the public and could activate an employment potential for nanotechnology. In this context, a systematisation of fields of education (R&D, production, marketing, quality, documentation) is needed which could be fostered by the creation and establishment of European nanotechnology standards or norms.

2.3. How can skill shortages/skill gaps be tackled and possibly prevented?

How to tackle or prevent skill shortages and gaps seems to depend on their causes. Are they temporary or permanent? Are they complex and difficult to acquire or quite similar to existing ones? The optimum solution will vary. In this context, the degree of flexibility and time of response to any demand from nanotechnology and nanobiotechnology are critical issues. According to the Bologna process, the time of response takes at least 5 years (i.e. 3+2 years) and in most cases probably 8 years (3+2+3 years). Thus, the challenge is the simultaneity of market introduction of products and the process of qualification. In such a situation it might be a useful starting point to seek for existing training modules which can be used, to modify existing skills for the new field or to make use of modular qualification systems. In such a situation of transition educational offers have to be made more transparent and young people have to be fascinated for the new technology to attract them to the field (Luther; in Part II). Exchange has to be facilitated via networks, competence centres, training networks (national/EU) with a special focus on education and training to initiate a collaboration among all stakeholders (e.g. by means of a round table of scientists and employers) and to ensure mutual communication between the public and industry. As already mentioned, a consequent assessment of both chances and risks of nanotechnology could activate an employment potential for and from nanotechnology and contribute to an avoidance of skill shortages.

All in all, the workshop participants came to the conclusion that due to the multidisciplinary character of nanotechnology and the abovementioned aspects cross-sectoral skills such as social skills and communication skills seem to be more important than pure technical skills.

New skill needs in nanotechnology
Summary and conclusions

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Cedefop

1. The 'revolutionary' character of nanotechnology

Nanotechnology is often referred to as 'revolutionary' by experts, probably due to its interdisciplinary character and, therefore, the potential to affect and alter many long-established science and industry fields. It operates with measures smaller than 100 nm, which allows manipulating the physical and chemical properties of materials at extremely small level and creating new ones for the sake of their utility. This technology opens up surprising possibilities of application of the materials, not experienced before.

Based on the sector of application, there are numerous nanotechnology fields, among them – nanomaterials, nanobiotechnology, nanoelectronics, nanoanalysis, nanooptics, etc. Accordingly, the sectors with the widest possibilities to apply nanotechnology are medicine, ICT, automotive industry, chemistry, food, and others. As the provisioned innovatory features of new nanotechnology end-products are expected to be of enormous significance and wide popularity, the estimates for the market of nanotechnology products are said to reach hundreds of billions of EUR already by 2010 (Donoval; in Part I).

2. Nanotechnology in Europe and its effects on skill needs

The perceived importance of nanosciences is growing, along with the investments made by the EU and several European countries independently for their development. At present nanotechnology in Europe is at its initial phase, which means more emphasis on research and less on production. Therefore the demand for highly-qualified scientists with university degree is the most extensive and visible. Nevertheless, in 3-5 years the need for intermediate level education and training is predicted by experts to grow, as the nanotechnology field will need staff, for example, for production, sales, management, clerical and office work. Daniel Donoval from Slovak University of Technology in Bratislava mentions estimations of about half a million new experts needed in the nanotechnology field in Europe within the next 10 years (Donoval; in Part I). Overall, the need for particularly qualified staff is expected in several nanotechnology fields of activities:

(a) research and development,
(b) production and manufacture,
(c) quality assurance,
(d) documentation,
(e) marketing and distribution (Abicht and Schumann; in Part I).

Jan Voves, from Czech University in Prague, makes a remarkable point about the general growth of jobs due to the development of nanotechnology. First, he confirms that in the early stage of development of nanotechnology there is an increased demand for the science and engineering workforce, and many new workplaces are created. Thus, a certain boom of jobs can be observed. Having said that, he argues that the technology development will gradually reduce the number of workers needed to produce a given level of output, and consequently nanotechnology will not create a significant number of new jobs in the long term.

Nevertheless, the positive effect of nanotechnology will be the general lowering of the cost of products, which will increase demand for goods, improve living standards, and eventually create the growth of employment (Voves; in Part II).

Based on the perceived trends of emerging skill needs, employers are going to be in need of people that possess wide interdisciplinary skills. To satisfy the forecasted demand, several experts emphasise that a new approach in education and training for nanotechnology is necessary. Taking into account the general suggestions by the experts, the preferred form of education would be constituted of the theoretical background of natural sciences (mathematics, physics, chemistry, biology) integrated with applied sciences. Thus, the prospective nanotechnology staff would possess interdisciplinary knowledge, supplemented also by some entrepreneurial and management skills. Due to the teamwork dominance in nanotechnology research and development, an employee needs to be able to communicate effectively with specialists in related nanotechnology fields, even if not being an expert in the sectors concerned himself. Employees with intermediate-level qualifications will need particular interdisciplinary knowledge, high level social competencies, and to be able to fulfil functions like quality assurance and documentation that have previously been carried out by staff with higher qualification (Abicht and Schumann; in Part I).

Apart from these specific professional skills, also intercultural communication skills, self-management, analytical, critical and 'out of the box' thinking have been named by experts as important skills for performing successfully in the nanofield. It was even agreed that social skills and communication skills should be regarded as more important that pure technical skills, due to the particular nature of work in nanotechnology.

Comparing specific skill needs when working for SMEs or global companies, Daniel Donoval pointed out a specific skill needs division. Thus, global companies are more in need of workers that are rather specialised in a specific nanotechnology field, as well as with well-developed intercultural communication skills; whereas, for SMEs there would be higher necessity for interdisciplinary staff, preferably strong also at leadership and entrepreneurship (Donoval; in Part I).

An important characteristic of nanotechnology, which cannot be neglected, is that it is and will keep being very fast-developing and highly dynamic. Therefore, it is indeed necessary to develop the concept of lifelong learning and training in this field, as skills once acquired might not be applicable anymore when the technology develops further on. Apart from formal vocational education and training, appropriate possibilities to acquire the necessary skills at the workplace should be made possible. Ways of ensuring it, offered by experts, include job rotation, obtaining specific experience abroad, and learning in groups or by problem solving (Freikamp and Schumann; in Part IV). Besides developing and modernising the continuous vocational training at the workplaces, employees' general participation rate in the training needs to be raised too, mostly by changing their attitude and fostering acceptance of such training (Luther; in Part II).

Another valuable option was pointed out by Jan Voves (in Part II), and it regards retraining of science professionals who have previously left scientific field and opted for work in another field. If it is possible to attract these professionals to nanotechnology, the retraining could take place in nanotechnology research centres all over Europe (the so called poles of excellence). That would provide an opportunity of sound training and provide with the new specific skills.

3. Skill shortages and gaps in emerging technologies

Given the key role of nanotechnology in the future industries, it is crucial for European countries and companies to work on identifying skill shortages and gaps that could possibly hamper its successful development. As the innovations and accompanying new qualification requirements are usually exceeding national borders, a common European perspective is believed to contribute significantly to national initiatives. Developing international cooperation and networking among European countries can help to improve the overall readiness to react in fast and appropriate manner to arising skill shortages. Equally important net result of the early identification actions is updating initial and continuous vocational training (Spath and Buck; in Part I).

It was pointed out by experts that, apart from purely quantitative estimations about the demand for particularly qualified employees, especially qualitative studies would carry more weight in the current situation. Thus, the central question should always remain 'which will be the skills employees will need to possess', instead of 'how many employees will be necessary'. The workshop participants discussed the possible methods to identify the emerging skill needs and possible skill shortages. As valuable options, regular surveys and interviews with experts of nanotechnology R&D were mentioned, as well as establishing EU level monitoring system. It was agreed that identifying latest developments in specific (key) companies and workplaces would be one of the most rewarding approaches (Dworschak; in Part IV).

A successful example of research activities is provided by the BMBF. It has applied various instruments to probe into present and future skills needs and situation with continuous training in German optics industry. Methods like telephone interviews, expert surveys and case studies have been applied to investigate the questions concerned in large companies, craft trades and SMEs (for details and results, refer to Luther; in Part II).

What concerns already existing skill shortages observable in emerging technologies and nanotechnology in particular, workshop participants pointed out the lack of specialists with basic natural sciences knowledge. Besides that, innovation management and cross-disciplinary communication are regarded to be the major skill gaps so far (Dworschak; in Part IV). In Germany, there is currently a major lack observed of technical workers with adequate qualifications. In the near future, the situation is predicted to worsen particularly as regards qualified personnel in mathematics, IT, natural sciences and technology (the so-called MINT) (Luther; in Part II).

To tackle and prevent skill shortages, timely and flexible reaction in vocational education and training system is significant. Currently 5 to 8 years are necessary so that the supply of labour force responds to the demand. To increase the flexibility of vocational education and training system, workshop experts have suggested applying existing training modules to update skills, and using a modular qualification system (Dworschak; in Part IV).

The FreQueNz network has designed a pattern for early identification of new and future qualification requirements which would contribute to a proactive reaction to these changes. Moreover, a monitoring methodology has been developed, which consists of the observation of trends with a high degree of change, and quick response to growing qualification demands (Spath and Buck; in Part I.). TRL model, presented by Coumar (Caneus), might also be applicable to assess the development on nanotechnology research and production, along with emerging skill needs in each phase (Oudea; in Part III).

Some activities have been reported by experts that try to find practical solutions and develop and implement the new educational and training approach in reality. Thus, isw Institute has drafted qualification profiles that overview the main emerging qualifications and their respective skills and competences. These could be considered when preparing measures for intermediate qualifications and further education. As the authors argue, the qualification profiles do not create any new professions themselves, but they may be of help for both employers and employees.

4. Sharing of research results and their transfer into policy and practice

With the ultimate goal to enhance the availability of research results and to foster the discussions on skill needs in nanofield, several networks are operating in Europe. FreQueNz network, Skillsnet and Nanoforum are among those.

Nanoforum is a network dedicated solely to gathering, summarising and sharing information concerning nanotechnology among European countries. Its activities have included publishing reports, carrying out an online survey, gathering information about education and training courses, and research centres in nanotechnology (Morrison; in Part III).

Whereas FreQueNz network and Skillsnet support researching and sharing results on qualification profiles and skill needs in nanotechnology, among other themes. They also contribute to the transfer of research results to the groups of people concerned, that is, employees, employers, training institutions, policy-makers, and social partners. Both networks organise conferences and prepare publications to disseminate the research results on skill needs (Zukersteinova; Steeger; in Part III).

5. Final conclusions

The workshop gave a clear message that nanotechnology is still developing. It has a interdisciplinary character and, therefore, it is difficult to identify future skill needs, especially at intermediate level. Europe already experiences a shortage of specialists and scientists with tertiary education, this shortage is expected to increase in the future. There is a need for monitoring intermediate skill needs and lessons could be learned from the past experience of other new and emerging technologies. As soon as nanotechnology goes into mass production, the shortage of skills in intermediary level occupations will become obvious. The debate on ethical and legal questions also has concluded that general risks and the social impact of nanotechnology are difficult to predict and more research is necessary.

Workshop participants agreed that an effort should be made to develop a road map for new skill needs in this field, with close collaboration between industry, science and education. This may help establish a system for technology monitoring and identifying occupational profiles, and organise regular surveys and data collection. To tackle rising skill shortages, a modular qualification system may help to integrate study fields of nanotechnology and nanosciences into existing educational programmes, including vocational training.

The common idea shared by the workshop participants was that the public awareness of the role and character of nanotechnology should be constantly raised to ensure its leading role in technological development in the future. There is a particular trend marked by some experts that the young generation is not very interested in technologically oriented studies. If that is not altered, it can create a serious lack of qualified staff for nanotechnology in the future. Therefore, it is highly important to work on increasing young people’s motivation to enter this field (as an example, BMBF has already taken on several activities organised especially for children, including travelling exhibition, brochures and teaching materials, etc.) (Luther; in Part II).

It was also proposed that education fields, concerning nanotechnology, should be systematised with the help of setting up European nanotechnology standards and norms (Dworschak; in Part IV). That is an open question to be considered in future actions.

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List of abbreviations

nm	Nanometer
BMBF	German Federal Ministry of Education and Research
NEMS	Nano electro mechanical systems
MNT	Micro and nanotechnologies
TRL	Technology readiness level