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Preface

The work programme "Integrating and strengthening the European Research Area" of the Sixth Framework Programme, promotes foresight as one of the major instruments to inform policymaking. Although many efforts have been taken to better describe and foresee the developments of science and technology (S&T) per se, relatively few studies have focused on the effects that S&T has on professions and the skills required to perform them. Therefore, this study for DG Research's Science and Technology Foresight Unit is focused on the links between research, science and technology, training and education, and new job profiles. The overall aim of the current foresight study is:

To assist European policy makers to identify future needs with regard to changing professional skills and new job profiles due to developments in Science & Technology, by providing a roadmap that will help anticipate upon the required response in terms of changes to the educational system, training practices and human resource strategies.

This report summarises the findings of the study, describing general developments in science and technology as well as in working practices, their effect on four economic sectors (agriculture, healthcare, transport and public administration) and their possible impact on professions within these sectors. In addition, we give information on scenarios of job profiles that were constructed on the basis of the analysis and that were used in a future-oriented discussion with a select group of European experts in S&T and education. Finally, we provide a roadmap that will help anticipate upon the required response in terms of changes to the educational system, training practices and human resource strategies.

1. Introduction

An important pillar of the knowledge-based economy of Europe is science and technology (S&T) development: it stimulates innovation, which in turn leads to value creation. By constantly improving our use of technologies, we can increase the productivity per worker and thus face global economic competition. The changes induced by globalisation and the knowledge driven economy are affecting every aspect of people's lives and require a transformation of the European economy. This was recognised by the European Council in Lisbon in 2000. The Council stated: "The Union must shape these changes in a manner consistent with its values and concepts of society […]" (Council of the European Union, 2000). It then established the Lisbon strategy that guides Europe "to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion".

Economic competition remains top priority for the EU; in 2004 the European Council re-launched the Lisbon Goals, refocusing its priorities on growth and employment: "The European area of knowledge should enable […] workers to acquire new skills. With that in mind, it is important to develop research, education and all forms of innovation insofar as they make it possible to turn knowledge into an added value and create more and better jobs" (Council of the European Union, 2005).

Developments in S&T are one of the factors that drive changes in professions: they significantly affect the knowledge and skills required to perform a job. One of the most obvious examples of this influence is the rise of the computer in the past two decades. Whereas there were still many jobs in the eighties that did not directly involve word processing or data entry, the majority of present-day jobs require at least a minimum of computing skills.

It is expected that S&T will continue to change the way people work, reordering the skills requirements for jobs. As it takes time to reorganize curricula of schools and higher education institutions, it would be wise to anticipate future changes in educational requirements and pro-actively adapt educational practices, thus smoothening the transition from one technological 'regime' to the next. This approach would minimize shortages in skills, as are nowadays perceived in the area of e-skills. This study focuses on the effect of S&T developments on educational requirements in the future[1].

[1] *Of course, we do not ignore the fact that there are other factors that have an impact on education requirements. Our focus will however be on the direct contribution that S&T has.*

1.1 Aim of the study

The overall aim of the current study is:

> To assist European policy makers to identify future needs with regard to changing professional skills and new job profiles, due to developments in Science & Technology, by providing a roadmap that will help anticipate upon the required response in terms of changes to the educational system, training practices and human resource strategies.

In European research programmes, foresight is used as one of the major instruments to inform policymaking. The document "Strengthening the foundations of the European research agenda" of this Specific Program, states that the coherent development of research and innovation policies will be supported by "the development and dissemination of S&T indicators, economic analyses, studies and the exploitation and synthesis of the results of foresight activities carried out at regional, national, European and international levels."

This report produces an overview of general developments in S&T as well as in working practices, their effect on four economic sectors (agriculture, healthcare, transport and public administration) and their possible impact on professions within that sector (Chapters 2 and 3). In addition, we provide information on scenarios of job profiles that were constructed on the basis of the analysis and were used in a future-oriented discussion with a select group of European experts in S&T and education (Chapter 4). Finally, we provide a discussion of our main findings and a roadmap that will help anticipate the required response in terms of changes to the educational system, training practices and human resource strategies (Chapter 5).

1.2 Approach

In this study we focused on the following tasks:

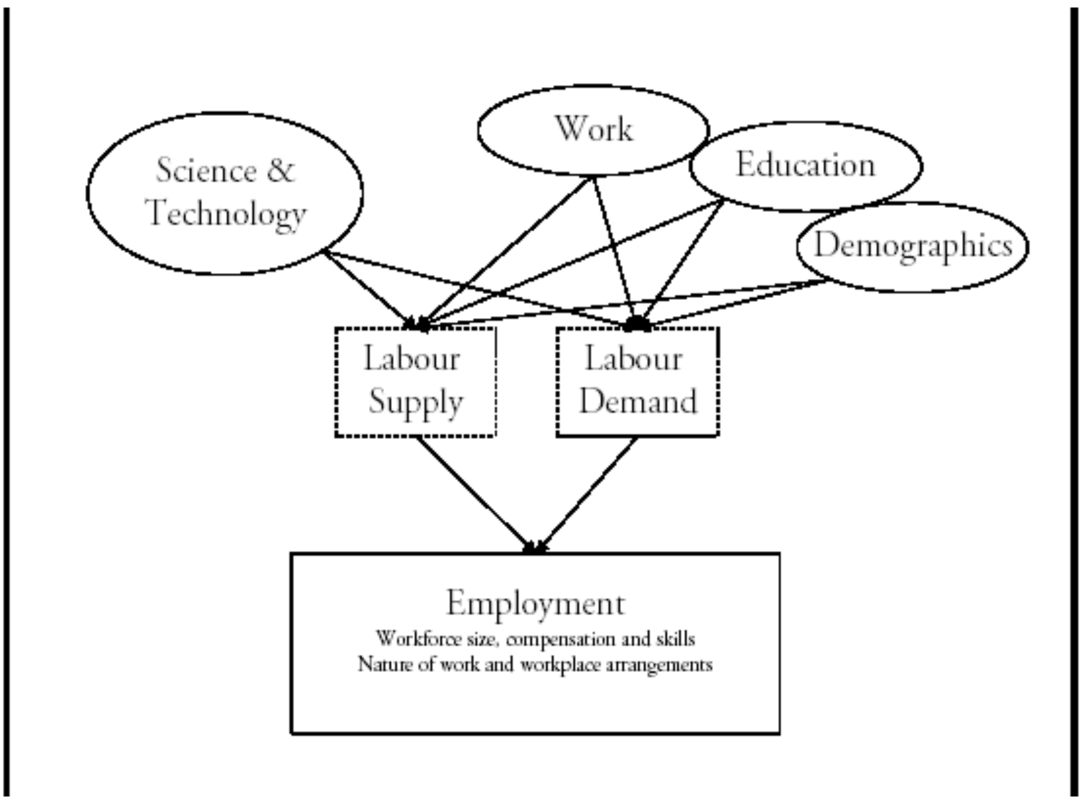
- Identifying the major drivers for changes in professions
- Identifying economic sectors to be analysed
- Developing scenarios
- Organising a workshop to identifying future needs with regard to changing professional skills and new job profiles due to developments in S&T

1.2.1 Conceptual framework and identification of economic sectors

Predicting the future is impossible, but giving a range of coherent pictures of possible futures – i.e. scenarios – can be very effective in informing decision makers. To determine the implications for education and training (and professions) in Europe due to the developments in S&T in the next ten years it is important to understand the relations between drivers of future of the European workforce.

Long- and short-term trends were identified as well as which trends will have large impacts and which trends are relevant as building blocks within a particular scenario exercise. Within this approach we need to establish trends that will influence the professions in the future. A very relevant example in this regard is The 21st Century at Work. Forces Shaping the Future Workforce and Workplace in the United Stated (Karoly & Panis, 2004) aiming to inform policy makers on the choices they make concerning training, education and other labour market issues. In The 21st Century at Work three major drivers are identified that have an impact on jobs in the next 10 to 15 years: demographic trends, technological advances and economic globalisation. According to the authors, these forces both shape demand and supply of the labour market and change the way people work, which has direct consequences for the education and training requirements, as described in the systems diagram given in Figure 1.

Figure 1: System diagram for the forces shaping the future of the EU workforce

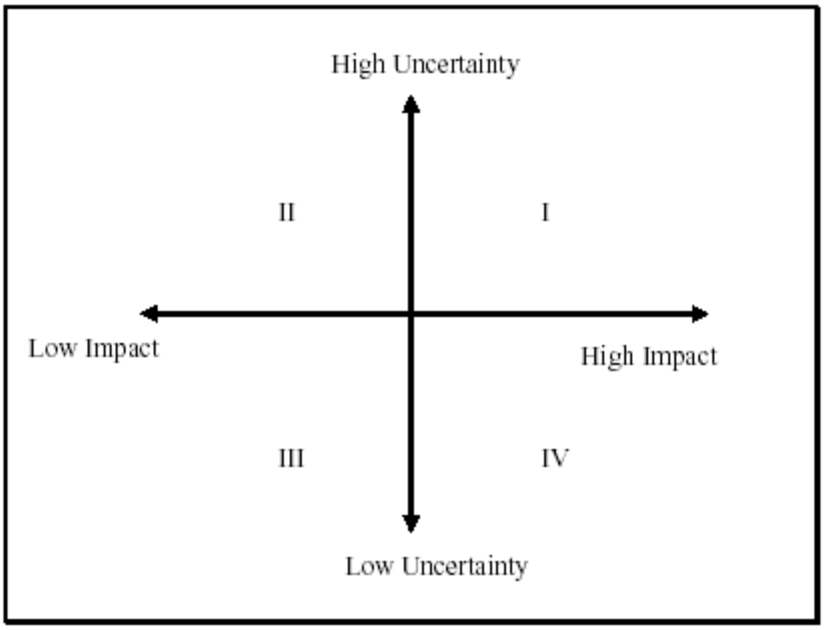


In this study, we elaborated on the system diagram as presented in Figure 1 and determined whether the systems diagram needs to be adjusted to represent the developments in Europe. E.g. the specific content of the labour supply and demand boxes depends on both the economic sector as well as the specific job description under consideration.

In addition, we clustered the factors identified based on their level of impact (on the functioning of the system) and on the level of uncertainty (with respect to the direction in which they would develop and what their consequences on the policy area would be). Factors that have a large impact on the functioning of the system were used to develop the scenario building blocks (the other factors can be ignored).

The drivers with a large impact and a low level of uncertainty remain constant among the scenarios – they are relatively stable assumptions about the future. The drivers with a large impact and a high level of uncertainty are at the core of the scenario development effort – they drive the differences among the scenarios. If there are many drivers, they have to be grouped based on interdependencies. By varying these (groups of) drivers, a set of scenarios can be composed (see Figure 2).

Figure 2: Driver types organized by impact and level of uncertainty



The developments that reside in the first quadrant of Figure 2 (high impact, high uncertainty) reflect one of the selection criteria for the case studies (i.e. economic sectors). In addition, the following criteria were used to select case studies:

• Policy relevance within the EU: The European Union organises its policy areas in activities. There are 32 activities within the European Union[2]. We selected those economic areas that are of the highest relevance for the European Union based on their budget. As such we selected: Health, Education, Agriculture, and Transport. In addition we selected Public Administration, although it is not mentioned in the 32 activities of the European Union. The reason is, that every public administration (at local, national or EU level) also builds on human resources that are affected by S&T developments.

• Anticipated changes in the nature of activities within the sector as a result of developments (e.g. expressed by the levels of R&D investments in a specific sector). We selected those developments that have a high uncertainty and a high impact on the knowledge society. Out of the five sectors mentioned above, the four sectors that are most strongly affected by new developments in science and technology are Health, Agriculture, Public Administration and Transport, which were further studied in a case study analysis.

1.2.2 Classification of economic sectors and professions

To describe the economic sectors, we used NACE (Classification of Economic Activities of the European Community), which is used as the standard Classification of Economic Activities in the European Community. The NACE-code system is based on the European standard for industry classifications and was introduced in 1970 and revised for the first time in 1990. The NACE is currently being revised again and the four-digit classification referred to in this study is based on the final draft of 2002.

For the analysis of professions, we used the International Standard Classification of Occupations (ISCO 88 (COM)). The ISCO 88 (COM) organizes occupations hierarchically. Jobs are defined as "a set of tasks or duties designed to be executed by one person" and jobs are grouped based on the degree of similarity in their constituent tasks and duties. This means that within a unit group jobs are grouped that may be different in terms of the output required, but are similar in terms of the abilities required to perform these tasks. Tasks and duties are thus grouped by level of complexity and skill specialization, and thus implicitly skill level is an additional essential aspect of the occupational categories. On the basis of skills, professions can be related to the ISCO groups:

- Type 1 Professions are based on ISCO 7,8 and 9. This type of occupation does not require a priori any type of higher education.

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[2] These activities are: Agriculture, Audiovisual, Budget, Competition, Consumers, Culture, Customs, Development, Economic and Monetary Affairs, Education, Training, Youth, Employment and Social Affairs, Energy, Enlargement, Enterprise, Environment, External Relations, External Trade, Fisheries, Food Safety, Foreign and Security Policy, Fraud, Humanitarian aid, Human rights, Information Society, Institutional affairs, Internal Market, Justice and Home Affairs, Public Health, Regional Policy, Research and Innovation, Taxation, Transport.

• Type 2 Professions are based on ISCO 4, 5 and 6. This type of occupation does not require a solid education in a particular subject. It does however require some form of education.

• Type 3 Professions are based on ISCO 2 and 3. This type of occupation does require a solid education in a particular subject area.

• Type 4 Professions are based on ISCO 1. This type of occupations does not require an education in a particular subject area a priori but does assume a solid education.

1.2.3 Case study analysis: focus on four economic sectors

The case studies examined how outcomes of main future S&T developments (primarily information technology, nanotechnology and biotechnology) will affect the activities undertaken in each of the sectors. In addition, the cases made an initial attempt to interpret what changing activities due to high impact technology developments mean for the future skills requirements in the sectors.

The case studies are fully presented in Annex A-D and were described on the basis of desk research (literature review, including reviewing relevant websites) and interviews with experts in the relevant sectors. More specific, we:

1. Reviewed sectoral features such as employment figures and skill distribution.
2. Identified main institutions within the economic sector
3. Described the current value chain for the selected institution
4. Analysed the impacts of future developments on the activities undertaken by professionals involved in performed activities within that specific institution

The analytical approach was built around the value chain framework, developed by Porter (1985), which is one approach to describe activities occurring in a specific sector while additional approaches could be used or included as well (e.g. choosing the top five professions within each sector). A value chain is the sequence of productive (i.e. value-added) activities leading to and supporting end use of a product or service (Sturgeon, 2001). Porter's model is made up by interrelated generic activities common to a wide range of organisations. The model distinguishes between primary and support activities and it consists of categories of activities that are generic and portrayed in a general manner (see Figure 3).

Figure 3. The value chain model

Primary Activities				
Inbound Logistics	Operations	Outbound Logistics	Marketing and Sales	Service
Receiving, Warehousing	Transformation of input into final product	Warehousing, Sending	Create sales opportunities	Customer support, Repair
Support Activities				
Infrastructure				Facilities, Finance, Management
Human Resource Management				Recruiting, Training, Rewarding
Technological Development				Development of processes and products
Procurement				Purchasing of goods and inputs

The value chain framework enabled us to address the vast number of interrelated activities included in the economic sectors in a structured manner. The generic value chain model is business-oriented, developed for the firm level and supports value chain analysis of specific organisations. The case study economic sectors obviously consist of several organisations and thereby several value chains. Porter recognises that one organisation's value chain is necessarily linked to the value chains of other organisations and refers to interlinked value chains as the value system. The case studies do not develop the complete value systems for each of the sectors but focus on the value chain of one main institution within the sector (i.e. in the agriculture sector the focus lies on a (grain) farm, in the health care sector the hospital is the central organisation, in the transport sector we choose a freight port and in the public administration sector security operations are the main focus). In each of the case studies, we have used professions within the sectors to further illustrate the effects of S&T. We note that all categories of the generic model may not be applicable to all organisations or the activities might occur in a different order.

Based on the analysis of the four economic sectors, we identified three main developments that have an effect on the type of skills required in 2015, which is further described in Chapters 2 and 3.

1.2.4 Validation of case studies and development of scenarios

We have validated the results of the case study analysis by interviewing experts in the field. More specifically, we have asked different experts to reflect on our analysis of each sector, how well the current educational system is able to deal with the upcoming changes as a result of S&T developments in each sector and whether and which changes in the educational system are needed to address possible bottlenecks. For the latter purpose, we have developed scenarios; we analysed technological developments in more detail to learn how these will result in certain and uncertain changes in related professions. Changes in professions were then grouped in terms of similarities and differences between the four case studies. For each major group of professional changes, we prepared a descriptive scenario, based on a mix of certain and uncertain elements. The scenarios were discussed during a workshop with European experts in S&T and education. The task of participants was to discuss what actual educational approaches would be needed to accommodate these changes (see Chapter 4).

1.2.5 Providing a roadmap

During a workshop that was held on November 8th, 2005 the scenarios were presented to 1) identify possible changes in higher education/research and structural changes in the year 2015 (and beyond) and 2) suggest policies for how to adapt the current structures to the differing circumstances in the next ten years. Thus, the most important outcome of the exercise was the discussion that emerged in the workshop after displaying the scenarios. The results were used to providing a roadmap that will help anticipate upon the required response in terms of changes to the educational system, training practices and human resource strategies as presented in Chapter 5.

2. Developments that influence professions

This chapter, based on previous work, discusses the developments within science and technology as well as education and work that will have an effect on economic sectors and professions.

2.1 Science and Technology progresses

2.1.1 Information Technology

Information technology (IT) has already changed our lives in many significant ways from the life of only 25 years ago. Advances such as the Internet and SMS are often quoted when people describe the sudden impact of IT development, but it is important to realise that the gap between a technological prototype and adoption within the market can range from 10 to 20 years. This means that many technologies that will be common in 2015 or 2020 are already available in prototype. The lag between a new idea and the market is substantially longer, 20 years or more. Therefore, the major technological developments listed below are relatively certain, although their potential and full impact on society is less clear-cut. Often this depends on external factors such as organisational structures and cultural biases.

There are many studies that attempt to list major developments in IT; based on the available literature Botterman et al. (2004) and RAND (2005) have suggested the following list of major future developments:

Wireless communication
Wireless communication (e.g. the WiFi standards and Bluetooth) will be an important trend in high technology environments. Nowadays, however, the question is whether there is enough time to become a standard, or whether it will be replaced by something more powerful (such as WiMax). A major bottleneck for wireless is the general lack of knowledge about security and security breaches, which leads to fear of abuse.

Broadband
The principal driver of the growth of broadband in the home is video rather than pure data (Botterman et al., 2004). Further increases in bandwidth are not required by present applications. Thus, increasing broadband uptake will require specific applications, while applications providers are waiting for further broadband developments.

RFID technology
Another wireless technology, RFID (radio frequency identification), will result in an exponential growth of information on where things are, market shares, target groups etc. This may lead to efficiency in logistical procedures, but opens issues of

- Privacy and security

- Data management: storage and accessibility of data
- Retrieval and longevity of data

Especially when used for humans (even “worthwhile causes” such as monitoring of elderly, children and chronically ill) these issues remain unsolved. People will not want to be ‘tracked’ all the time, as privacy increasingly becomes an issue. In addition this technology raises issues about the management of data generated by tags and the regulation of access to this data.

Convergence of technology

Convergence of technology can lead to increasing simplicity for users by hiding complexity of software and technology. Things will communicate with other things in an effort to make life easier for people, and communication will be dominated by machine-to-machine communication.

Opinions vary on the type of information technology development to expect in the near future and on the likeliness of major trend breaks fuelling developments. A number of experts in the field feel the most far-reaching changes in the next decade are not likely to be the result of dramatic new innovation. Rather, they will almost certainly result from the focusing, refining and merging of existing technologies and their extension to more areas of our lives (Phillips, 2004). These experts state that technology trends are all clear: there are no trend breaks, surprises will be in the way existing technology is used in new ways and services develop. Others do not reject the possibility of a trend break, introducing the Internet and its organisation as a driver here: Internet pushes control to the edges, not the centre. Breakthroughs are developed at the edges and innovations based on these breakthroughs cannot be predicted.

2.1.2 Biotechnology

As with many developments, those in biotechnology could herald new developments for good and for bad. Antón et al. (2001) describe as most significant effects of biotechnology 1) increased quality and quantity of human life 2) eugenics and cloning. Advances in biotechnology lead to better disease control, customized drugs, modified foods, gene therapy, age mitigation and reversal, memory enhancing drugs, prosthetics, bionic implants and possibly animal transplants. New technological applications can foster improvements in human knowledge and individual well-being: e.g. medical breakthroughs that cure or mitigate some common diseases and stretch the average lifespan, or applications that improve food and potable water production (NIC, 2004). The impact of IT developments on healthcare will be high, in particular through the convergence of computer science and biology (bioinformatics).

The combination of biotechnology and medical technology offers possibilities like tissue engineering, in which new parts grown in a lab can replace pieces of skin, bone, cartilage or 10 even organs and this may develop into body parts on demand (Systens New Technology, 2001). Present-day technologies are being used for ultra-fine surgery, as human precision is not adequate enough at the single-cell level (Kamphuis, 2004).

Two developments should be particularly mentioned:

Genetics: mapping the genome and enabling e.g. personalized drugs:
Personalized drug treatment based on the genetic code may only be 10 years away. In the NIC report (2004) possible breakthroughs in biomedicine are provided that could lead to an antiviral barrier, blocking the spread of diseases such as HIV/AIDS. Developments in the realm of US Homeland Security led to therapies that might block a pathogen's ability to enter the body, which has healthcare applications beyond protecting the US from a terrorist attack. Other developments are genetic profiling (with positive applications in healthcare but negative applications in e.g. insurance), gene therapy (enabling e.g. anti viral therapy and (in-body) organ reconstruction), stem cell research, and finding of DNA signatures for specific diseases.

Functional foods (additions to foods increasing health benefits):
Normal consumer foods will contain more and more additives that have a 'beneficial effect' on the consumers' health (nutraceuticals/functional foods). Existing examples are margarine that reduces cholesterol or milk with added calcium. The whole vitamin industry is a growth market. Genetically modified foods can provide the consumer with added advantages such as extra vitamin A ('golden rice') or foods that do not cause allergic reactions (Antón et al. 2001).

2.1.3 Nanotechnology

Developments in nanotechnology will enable mechanical components to become smaller until the point that it becomes molecular manufacturing (Syntens New Technologies, 2001). An added advantage of building machines on nanoscale is that – eventually – they will consume less materials and energy. Developments on the nano-scale lead to faster and cheaper semiconductors, which will increase the availability of low-cost computing in all kinds of consumer appliances (Antón et al. 2001).

Complex machines can become smaller and more portable. Medical technologies can be built into the patients' body: special molecular machines that can clear up arteries or measure sugar-level of the blood – a lab-on-a-chip can provide basic health information that could lead to personalized treatment or a personalized diet. Locally implanted electrodes may combat pain. An implanted device can provide the right dosage of medicine over a longer period of time (e.g. implanted contraceptives) and reduce dosage. Drug delivery through nano-sized devices will eventually find its way into the mainstream of medicine.

In the longer term (more than 20 years) developments in nanotechnology and molecular manufacturing could lead to a future that is by definition unpredictable as the basic rules of production and economic scarcity are undermined.

Keyboard and screen cannot become much smaller; this will limit mobile devices unless there are drastic changes in the interface technology. There is slow improvement in voice recognition and brain-computer interfaces are in an experimental stage at this time (RAND, 2005).

2.1.4 Cognitive Science

Cognitive science (CS) is an interdisciplinary field of research, drawing on psychology, neuroscience, artificial intelligence/computer science, and philosophy in developing theories about (human) perception, thinking, and learning[3]. Cognitive science combines the humanities approach with natural science experimentation as well as synthetic constructions of the information sciences. It views cognitive processes as calculative activities and is not limited to natural cognition: artificial cognitive systems are also under scrutiny.

The cooperation of mixed cognitive systems (where humans interact with computers) has become a focus of recent developments in the field. As information processing (of humans and machines) takes an ever more prominent role in our society, so does the research in cognitive sciences. Strube (2001) discusses prominent areas of research such as the development of intuitive information and communication systems – shaping technologies to adapt to humans instead of the other way around.

2.2 Work becomes more flexible

The developments in the field of IT as discussed above have changed and will remain to alter the balance of how people spend their time, most likely obstructing the division of work and leisure time. As workers are increasingly becoming connected everywhere and around the clock, it becomes more difficult to 'switch off' and achieve a separation of work and personal lives. The effects of technology on work express itself in at least three layers:

- At the "macro" level, technology can have an impact on the structure of professional organizations and the way people are employed;
- At the "meso" level, people working in a different environment will still require interaction to get their professional activities accomplished; however, the location of work has and will become more flexible
- At the "micro" level, people require will need to continuously adapt their skills set to the changing environment to enable dealing with new technologies and their effects.

The following sections review in more detail each of these layers.

Organization structure and employment

In 1995 the OECD published a report with expectations regarding the effect of technology on work. Changing technology shifts hierarchical management to delegation of responsibility and autonomy creating a class of independent workers and a surge in virtual organizations (Wagner et al, 2004). A more flexible organization that engages in task related contracts can compose, dissolve, and recompose teams or technology capabilities based on demand. In such a future a major organizational challenge is to resolve the tension between

[3] *The word cognition describes all mental activities of humans (perceiving, acting, learning, remembering, thinking, deciding, speaking, and understanding) as well as those of other animals.*

the need for a secure environment to nurture employee initiative and the potential insecurity due to the unfamiliar work relationships (OECD, 1995).

In an increased number of organizations and sectors people will work as independents. People do not necessarily have to identify with 'the company' and may form groups (networks or guilds) around a common feature or identity. These networks or guilds could provide services for members. On the other hand many experts feel that although there is a trend toward freelance work, there is a tendency to overestimate the future role of contract work and the effectiveness of project teams put together in 'Lego style'. Due to the benefits of shared experience, synergies and personal 'chemistry' it is expected that stable, long-term employment will still be valued in the future. ICT can facilitate good human interactions, but it cannot create them.

Telework and co-location

Telework is expected to become an important facilitator of diversified job tenure patterns (OECD, 1995). Britton, Halfpenny et al (2004) test the proposition of Castells that there are two potential consequences of the introduction of information technology into the workplace: dispersal of the workforce and individualization of work, including the spread of teleworking. The study argues that, despite changes in working practices resulting from heavy investment in information technologies, the potential of formal and informal face-to-face interaction to generate cohesion and trust, and maintain competitiveness, encourages firms to locate in the city center and curtails the attraction of teleworking.

Many experts support these findings. Nevertheless, it has thus far proved very elusive to provide the common ground, tacit understanding and shared emergent social meaning that actual physical proximity provides.

Thus, there has not yet been a good way of replacing proximity. Computers have not reduced the need for face-to-face contact. Simulations have shown that groups communicating through computers came up with the more complex solutions than groups working in proximity, but the outcome was the same. Whatever technology has to offer, there will always be a social dimension to interaction, which cannot be replaced by technologies alone.

Skilled and un-skilled work

The German Federal Ministry of Economics and Technology & Federal Ministry of Education and Research (2002) expect that in a few years processing information will be the core task for 80% of all people at work. This and other future technological advances and greater economic integration of national economies are expected to increase the demand for a more highly skilled workforce. The overwhelming evidence regarding technological advances seems to point towards favouring more-skilled workers ("skill-biased technological change"). Karoly and Panis found "a steady rise in the share of jobs requiring no routine cognitive analytic (problem solving) and interactive (communication) skills, especially during the 1980s and 1990s" (2004, page 109).

This development is also to be expected in economies where large fluctuations in demand and increased speed of development make for a volatile business environment, characterized by labour flexibility. People may need to accept losing their jobs more than once in their career. However, in a fast changing working environment, workers must constantly keep pace, which is likely to create difficulties for workers who re-enter a professional field after a time of absence or unemployment. This lays the burden of keeping up-to-date (and thus for life long learning) on the (knowledge) worker.

While it is clear that technology – and in particular information technology – will have a large impact on skilled work and probably on the management and structure of many organizations, Munro and Rainbird (2002) put forward that technology is not the primary mover of change for unskilled work. This suggests that future technology will not have a large impact on unskilled work in general. There might be changes to unskilled work but those will not be driven primarily by technology change. Instead pressure to cut costs, achieve flexibility, improve the quality of public services and meet the needs of wider organizational change are main drivers.

In an early OECD report (1995) information technology was thought to replace human operator skills and undermine certain traditional craft professions such as technical drafting, typesetting, etc. Bain et al (2002) take this view even further arguing that much of future office work will be call-center employment – requiring fewer skills than expected. Such a development would create a dichotomy in the workforce widening the gap between skilled and unskilled work.

The development has been made possible by Internet and its integration to form multi-media customer contact. As more efficient technology for monitoring develops, it is expected that the unskilled workers in call centers and similar office work will be framed by Taylorist practice with little autonomy and performance pressure (Bain et al, 2002).

2.3 Education needs to be updated

The OECD (2001) concluded that the development of the knowledge economy is changing labour market demands for competences and skills. High levels of education and literacy are the key principal competencies demanded in the knowledge economy. Basic general education provides workers with the core academic and cognitive competencies required to participate most effectively. However, so-called "workplace competencies", e.g. communication skills, problem-solving skills and teamwork ability are important for new organization practices and knowledge work. A more recent RAND study confirms this conclusion: shifts in the nature of business organizations and the growing importance of knowledge based work favor strong non-routine cognitive skills, such as abstract reasoning, problem solving, communication and collaboration skills (Karoly and Panis, 2004).

Being able to update your knowledge base fast enough and apply that in new ways to achieve a valued goal will become increasingly important in the future (Seltzer and Bentley, 2000). This can only be achieved when schooling and the educational system aim to develop creative learners. A creative learner is someone who has:

- The ability to identify new problems, rather than depending on others to define them;

- The ability to transfer knowledge gained in one context to another in order to solve a problem;
- A belief in learning as an incremental process, in which repeated attempts will eventually lead to success;
- The capacity to focus attention in the pursuit of a goal, or a set of goals.

Malles (1998) has looked into the effects that increased international trade in professional services has on professions and higher education. The main issue here is that internationalization of work leads to the need for harmonization of degrees, standards, qualifications, and degrees.

The paper also specifically addresses international trade in educational services. The implications of increased trade in this sector are:

- Need for systems that can handle international student mobility;
- Technological change is viewed as one of the most important factors contributing to increased international trade in educational and training services. Telecommunication, cable and satellite make distance education possible;
- Need for methods to monitor and evaluate foreign education.

Changing the system

In technical disciplines one fifth of the knowledge can be expected to be obsolete within a year (German Federal Ministry of Economics and Technology & Federal Ministry of Education and Research, 2002). A similar argument can be made for many other disciplines. Consequently the body of knowledge has a limited shelf life. However, while the focus of education will need to shift from knowledge to skills, it is only a shift and not a replacement. A certain level of knowledge transfer will remain necessary to function. In general education will move towards developing analytic capabilities.

The OECD stated in 2001 that it is unclear whether the ability to gain workplace competencies is related to education. However, there is a body of literature on experiments – dating back at least three decades – on how to foster the development of so-called higher-order thinking skills (HOTS, Hamer et al., 2004; Seltzer and Bently, 2000; Van Rossum and Schenk, 1984). Despite this, national education policies are often not focused on these types of issues in education. An additional problem with educational reform is that –as most professionals – teachers do not necessarily like (or embrace) change: in particular change to one's own views on teaching and learning (Trowler and Cooper, 2004; Trigwell and Prosser, 1996). Changing the system requires changing the views of educators, educational managers, students and parents (Hamer et al. 2004) and change requires time and motivation to reflect on existing views and ideas.

The burden of education and learning

Work in the future will demand more adaptable skills and a greater capacity to learn continuously (OECD, 1995). Due to expected future high levels of innovation, rapid product cycles and firms are expected to put even more emphasis in the future on new, flexible ways of employing knowledge workers.

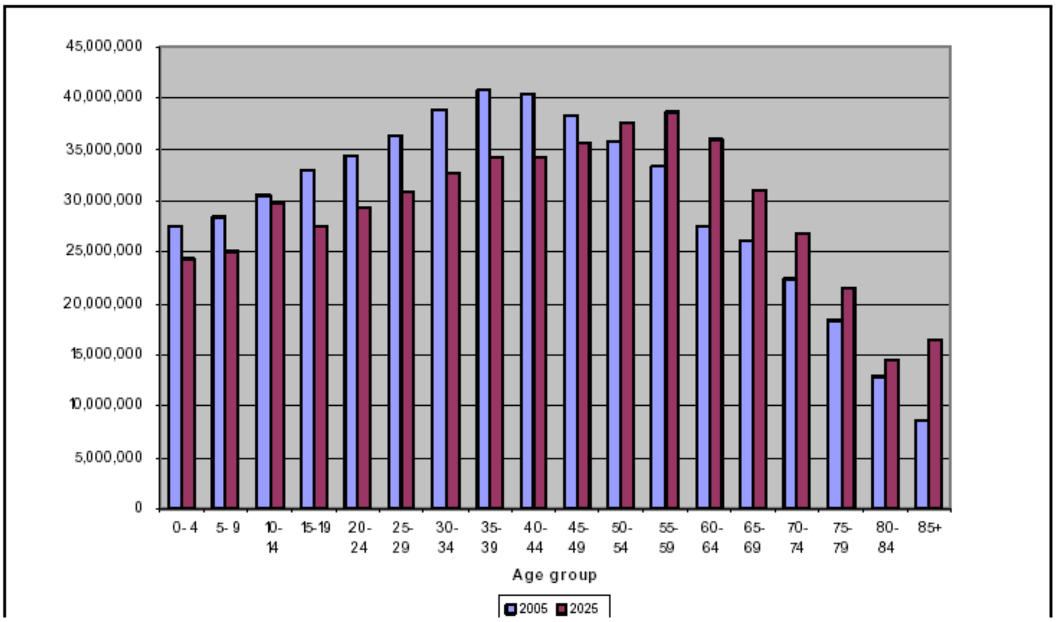
Less stable employment relationships highlight the importance of life long learning (Karoly and Panis, 2004). Employers will need to create conditions and structures that will promote individual learning and a constant process of further and advanced training at work in order to have competitive personnel, which will be their main asset. Work based learning and training will be a large component of future work (German Federal Ministry of Economics and Technology & Federal Ministry of Education and Research, 2002).

Rapid structural changes and need for new professions and modernizing existing once requires rapid reactions in training personnel (German Federal Ministry of Economics and Technology & Federal Ministry of Education and Research, 2002).

2.4 Demography: people become older

The aging of society in Europe over the next 25 years is an acknowledged development while the large population growth in the less developed regions of the world increase the mismatch between workload and workforce. Figure 4 shows the expected demographic shift in Europe over the next 20 years. It is clearly visible that the peak shifts from the economically most productive age groups (30-50) to the early retirement age groups. Also the number of 85+ citizens nearly doubles.

Figure 4: Demographic chart for Europe (2005 to 2025)



Source: US Census Bureau, International Database 2004

The effect of the age structure on the labour force is aggravated by low fertility in Europe and early retirement. A United Nations study (UN, 2000) estimated that the European Union (EU) might lose 12 percent of its population by 2050. The median age within the EU will rise from almost 39 in 2000 to 46.4 in 2025, while share of population of 65 and older will increase from 16.4% to 23% in 2025 (almost 29% in 2050).

Currently the retirement ratio in the EU is about 4 (four people in the workforce supporting one elderly person) but this ratio will reduce to 2 by 2050 without policy measures (Rix, 2000). The UN report also includes a table with retirement ages that are required in 2050 to keep the retirement support ratio at the current level. The table is cited in Rix (2000) and shown in Figure 5 and indicates that by 2050 the retirement age may need to be raised to approx. 75 years. Assuming a more or less linear development in the retirement support ratio, this would imply that by 2025 the official retirement age in Europe should perhaps be approximately 70.

Figure 5: Retirement Age Required to Maintain 1995 Aged Support Ratio, Selected Countries and the European Union

Country/Region	Required Retirement Age in 2050
France	73.9
Germany	77.2
Italy	77.3
Japan	77.0
Russian Federation	72.7
UK/ Northern Ireland	72.3
United States	74.3
European Union	75.7

Source: United Nations Secretariat. Replacement Migration, ESA/P/WP.160 (New York: UN, 2000) Table IV-10

3. What changes in skills are necessary?

It is uncertain how the skills that are required by the workforce today need to change to address the needs of tomorrow. What is certain is that the skills required in the year 2015 will be different from the skills that are taught today. This is the result of developments in science and technology (S&T), demographics, and the organization of work. Three main developments can be identified that have an effect on the type of skills required in 2015:

- The half-life of knowledge is decreasing;
- The amount of information is increasing; and
- Concurrent pressures of generalisation and specialisation of the workforce.

This finding is based on the analysis of four economic sectors: the agriculture sector, the health care sector, the public security sector, and the transport sector. For each of these sectors we have analysed a relevant organisation that will face changes in the future as a result of above-mentioned developments. For the analysis, we used the value chain framework designed by Porter, as described in Chapter 1. In particular, we have studied the impact of S&T developments with a focus on biotechnology, nanotechnology, and information and communication technologies.

In annex A-D we describe the four case studies, each focussing on one example of an organisation in a particular economic sector, ranging from agriculture to transport. These organisations are: a crops farm for the agriculture sector, the hospital for the health care sector, the public security operations in the public security, law and order sector, and the freight handling terminal for the transport sector. Based on their value chain we identify the most important activities in these organisations and analyse how the developments in science and technology affect these activities. We give examples of some of these activities. For more detail we refer to the annexes.

In the following sections we describe the three main developments in more detail. We show how these developments surface based on trends we have observed in each of the four economic sectors. Parts of our findings are based on interviews conducted with various experts in the fields of the four economic sectors. In each subsequent section we present the developments and describe what their overall effects are on the skills required in 2015. We substantiate these findings by presenting examples that highlight the different aspects of the effects on several sectors. We show how two developments give rise to a third effect. This third effect is shown to have two different interpretations. We show that based on our initial analysis it is not possible to determine which effect will be dominant. Further analysis on the uncertainties underlying these findings will shed more light on this issue.

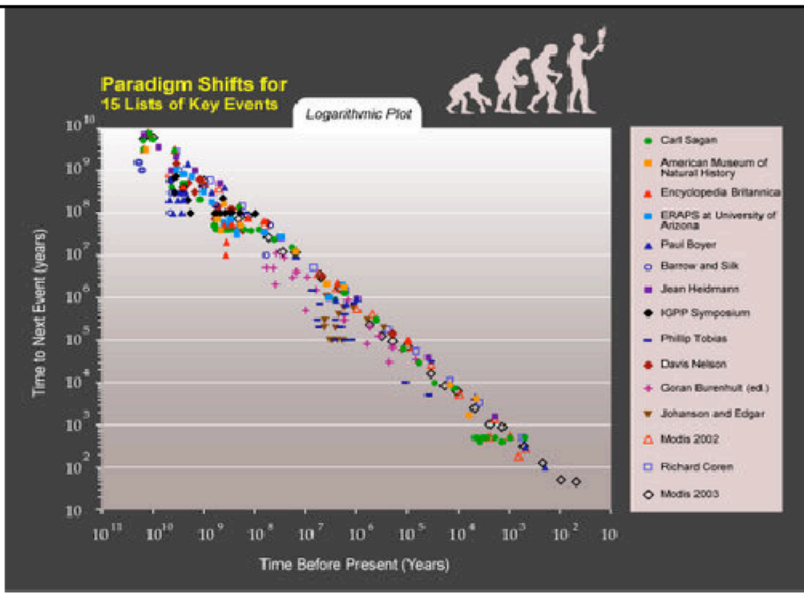
In section 3.1, we elaborate on the increase in dynamics of knowledge that has an effect in particular on the agriculture and health care sector. In section 3.2, we describe the effects of the increase of information on the four economic sectors under consideration. In particular, we focus on the agriculture sector and the transport sector. In section 3.3, we describe how S&T developments lead to a generalisation and a specialisation of the workforce. In this section we will focus on the health care and public security sector.

3.1 The dynamics of knowledge will increase

The half-life of knowledge is decreasing. Yesterday, it was still possible to get educated for life at university or elsewhere. Tomorrow this will no longer be the case. It will be necessary to maintain a portfolio of knowledge. These effects are the result of trends in science, technology, demographics, and the organisation of work. Trends in biological sciences have shown that half-life of knowledge is decreasing (WBBA, 2005). The half-life of knowledge can be interpreted as the time-scale in which knowledge is replaced by new knowledge. Therefore, the half-life of knowledge is directly related to shifts in paradigms within the biological sciences. However, not all skills have the same half-life. Some have a short half-life while others last longer. It is then natural to distinguish between skills with a short half-life and skills with a long half-life (Knight, 1997).

When plotted on a logarithmic scale, 15 separate lists of paradigm shifts for key events in human history show an exponential trend (see Fig. 6)
Lists prepared among others by Carl Sagan, Paul D. Boyer, Encyclopaedia Britannica, American Museum of Natural History and University of Arizona, compiled by Ray Kurzweil.

Figure 6: paradigm shifts for 15 lists of key events



Source: Wikipedia.org

More generally, especially in science and engineering the half-life of knowledge is getting shorter. The half-life of ICT knowledge is already considered to be less than nine months (L'Express, 2005). Indeed, more generally the shifts in paradigms occur ever more often as is shown in Figure 6. In this figure, the paradigm shifts for key events in human history are shown (Wikipedia, 2005). This decreased half-life will cause an increase in the possibilities and variety of tools for various professionals as is shown in the two examples presented below.

3.1.1 The crops farm could face a range of genetically modified crops

Farming has been stereotyped as working on the fields emphasising mainly manual labour. Current farming is more than simple, one-dimensional labour. Indeed, agriculture is more than simply ploughing the soil or raising a cow, but instead encompasses cultivation of the soil, growing and harvesting of crops, breeding and raising of livestock, dairying and forestry (Micheal et al., 2005).

Modern agriculture in general and the crops farmer in particular relies more and more on engineering, technology and the physical and biological sciences (Micheal et al., 2005). Today's farmer employs various machines like tractors. Due to developments in the biological sciences, farmers are able to use pesticides to increase crop yields and ease the maintenance of the fields.
The effects of the decreasing half-life of knowledge are also apparent for the crops farmer. We found that three stages in the development of genetically modified crops can be distinguished. They differ from each other by the traits that they provide. The first stage concerns only traits that support the immediate objectives of the farmer, like resistance to pests. The second stage is related to characteristics that favour the current end-user, like high-oleic soybeans. The third stage concerns traits for new end-users, like the pharmaceutical industry.

The crops farmer has to cope with an increasing amount of genetically modified crops whether they are first, second or third generation crop types. It will no longer be possible to use the same techniques and produce the same crops as was done before. The developments in biotechnology will provide ever more different crop types. Since the half-life within biotechnology is decreasing, so the half-life of each crop type is decreasing.

3.1.2 The surgeon and other professionals face new tools requiring new knowledge

The effects of the decreasing half-life of knowledge are also apparent for the hospital. Spin-offs from both biotechnology and physics lead to tools for surgeons, like the MRI scan and gene therapy. Since biotechnology and science in general face a decrease in half-life, the tools that the surgeon will face change more rapidly.

The health care professional will have to be able to understand the new tools requiring him to obtain new knowledge. The first MRI exam performed was on July 3, 1977 and was further developed in the 1980s and has revolutionised the treatment of low back pain (Gould, 2005; Spine-Health, 2005). The MRI scan determines point by point which tissue type is located where in the body. This allows for the construction of a full 3D picture. The interpretation of these pictures determines whether the MRI scan is useful. In order to be able to interpret the pictures correctly the user, or health care professional needs to be able to understand it. The health care professional using this device had to acquire new skills in order to be able to use it effectively. This is an example where the introduction of new tools requires new knowledge to be fully effective.

Specialists such as surgeons, used to have a limited set of tools: scalpel, needles, forceps, and scissors. However, new and more effective surgical tools, such as laser and radiation, are replacing these traditional surgery tools. Even newer tools are laser scalpels and "smart" scalpels that detect e.g. cancer cells (SEER, 2005).

With the increased dynamics of biotechnological knowledge it is easy to see that the surgeon will face many new tools in the future. It has been shown that the time to do a full DNA analysis has been reduced from hours to minutes (Cooper, 2005), thus potentially increasing the productivity of lab personnel. This is an example where genetic diagnosis becomes possible in routine tasks. With better DNA analysis it is possible to diagnose patients for monogenetic diseases and treat them subsequently with gene therapy. These advances may lead to better disease control.

Nanotechnology is capable of revolutionising the health care sector. It will provide new tools for the surgeon of tomorrow. These tools focus on new ways for diagnosis and new methods for drug delivery. An implanted device can provide the right dosage of medicine over a longer period in time (Admiraal et al., 1999). Furthermore, nanotechnology will allow minimal invasive surgery to be performed. For example, heart surgery can be robotically performed through a tiny opening in the chest. To be able to effectively use these new tools, the health care professional will have to acquire new knowledge, which involves training and possibly organisational adaptation.

3.2 Increase in the amount of information

There is an increase in the amount of information that tomorrow's professional has to consume. Take the growing Internet. As Internet grows, more information becomes available and there is a low threshold to get access to this information. This increase in information is also the effect of developments in science and technology. It is a consequence of the increased amount of detail we can explore in different areas. The developments in ICT make it possible to generate, analyse, and disseminate this amount of information.

A good example of a dramatic increase in data is the amount of data that will be generated by the various detectors at the Large Hadron Collider (LHC) in Geneva, Switzerland. At the previous collider, the Large Electron-Positron Collider (LEP) the amount of data that was generated was 500GB/year. When the LHC is online, it will generate more than 600 MB/s of data at start-up in 2007 (Wikipedia, 2005). The LHC is expected to generate more than 20 terabytes of data every year. This is roughly equivalent to the storage capacity of 20 million CDs (BBC News, 2004; Shiers, 1998; Gaspar, 2002). This increase in data of about 1 billion percent is the result of new technologies that enable both a high acceleration of protons, giving an abundance of particles after the collision as well as better techniques to track the created particles after the collision. With this dramatic increase in data, new technologies and methods of analysis had to be invented.

The results of these efforts will include the construction of GRID computing. Although this example comes from high-energy elementary particle physics, this effect can also be observed in other activities such as the farmer that will face an increasing amount of information due to precision farming. Due to the development of RFID an increase in information can also be found at the freight-handling terminal.

3.2.1 Precision farming increases the amount of data for the farmer

The amount of data that is generated when precision farming is practiced is enormous compared to today's standards. Precision farming or precision agriculture is an agricultural concept relying on the existence of in-field variability. It requires the use of new technologies, such as global positioning (GPS), sensors, satellites or aerial images, and information management tools (GIS) to assess and understand variations. Collected information may be used to more precisely evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.

The farmer will have to be able to cope with this increase in data. Currently, the farmer employs tools like tractors to effectively plough the land, pesticides to protect their crops from pests, and fertilizers to increase the nutrients in the soil. The application of these tools depends on the data the farmer currently has. These range from date, time, and temperature to humidity of the soil. However, these measurements are all made at a single location and are subsequently extrapolated to the remainder of the land. Precision farming allows the measurement of conditions on a multitude of locations simultaneously and wirelessly by nano-probes and thus will do away with inaccurate extrapolations. The nano-probes generate a data array that can be analysed. As a consequence, the farmer will have to be able to deal with this increased amount of data.

The increase of information turns today's farmer into a businessman in the future. The prices of the land and the varying crop prices can pose a threat to today's farmer (Time, 2004). The crops market may present unforeseen changes. This risk can be minimised by carefully planning the combination of crops they grow. When the price of one crop drops, other crops can still provide for enough income for the farmer (USDoL, 2004). This strategy is identical to having a portfolio of shares on the stock market. The more crops the farm cultivates, the more information the farmer has to be able to process. The developments in biotechnology allow for an increasing variety of crops. To have the best possible portfolio of crops the farmer has to be able to track all the information on these crops. This increase in information will necessitate increasing business management skills to people that operate in the farming sector (Time, 2004).

3.2.2 RFID increases the amount of information in the terminal

The amount of data in the terminal will increase. The increase in data will primarily be the effect of developments in RFID and other tracking tools like GPS.

Already the terminal is heavily automated. All the information on the content of the various containers is available in various databases. When a ship enters the terminal, the man that controls the gantry crane knows which container to pick up. The person controlling the straddle carrier that transports the container from the dock to the stack knows where to put the specific container. The database also lists the pick-up time of a particular container. The person controlling the rail-mounted gantries then uses this information. Although all information is already listed in several databases, the handling of the containers is still done by hand.

The terminal will be automated even further in the future. This automation is primarily possible due to developments in RFID. The various cranes, like the gantry and rail-mounted gantry crane, can do the writing down of the container number using RFID in the future what is currently done by hand. Already some gantry cranes are equipped with such devices. However, these possibilities have not yet been implemented widely.

Due to RFID and other developments in ICT, such as increasing processing power and the Internet, more information on the status of the various containers is required. Yesterday, uncertainty about delivery times was high and accepted. The consequence of the uncertainty was that end-users had an extensive stock available in case the goods would arrive late. Since more information can be obtained in a digital format using for example RDIF, end-users can more easily manage their stock if they know where a particular container is in the chain from departure location to target location. The end-user will therefore demand more information from the terminals to improve their own stock management and employ just-in-time management.

Another development in the transport sector will increase the amount of information that has to be handled in the terminal. Currently an average freight ship can hold up to 7000 containers. This capacity will increase in the future leading to larger amounts of information. Although the size of the freight ships increase the amount of time available to load and unload will remain the same. This can only be realised when advanced techniques are employed to speed up the process of distributing the various containers. This means that more information has to be handled in the same amount of time.

3.3 Does the workforce generalise or specialise?

A trend of generalisation of the workforce can be identified. In order for supervisors to maintain good communication between their employees he has to become a generalist, being able to switch between various highly specialised areas of knowledge. With the increase of information and the increase of dynamics of knowledge it will be important for those that operate currently in a relatively stable environment to be able to develop strategic decisions.

Currently, the professional faces the increased dynamics of knowledge. The manager of today has climbed up the ranks in the organisation. This allows him to understand and know what his employees are doing. The supervisor cannot reasonably be expected to be up to date and be able to understand everything, when the knowledge that they use changes. As the half-life of knowledge decreases this gap will increase ever further. To remedy this effect, it will be important that the supervisors become generalists when they climb up the ranks.

The increase in information and the dynamic knowledge requires professionals to be able to develop a broad overview of the developments occurring. Within a relatively stable environment, it is easy to have a broad view of the developments occurring and maintain a specific course. Only when this environment changes will it be necessary to develop a vision for the future taking into account a large range of knowledge, which does not allow much specialisation. Trends show that the environment in every economic sector we have analysed becomes more dynamic. This means that in currently relatively stable economic sectors the professional will have to develop a vision for the future. These skills are already commonplace in the corporate sector, where the wishes of the consumer change very rapidly. The ability of making strategic decisions will require a large spectrum of knowledge leading to less specialisation.

The development of generalisation can be identified in three economic sectors. The sworn-in officer will have to manage expert analysts. These analysts will be able to cope with the new developments and can provide the officer with the data that allows him to prosecute the criminal. The supervisor of the doctors has to switch between various experts. As the knowledge of the employees deepens the supervisor had to be able to deal with meta-knowledge. The farmers will become rural businessmen. Just as businessmen make strategic decisions, so the farmer has to be able to make strategic decisions in the future.

Or does the trend indicate a specialisation of the workforce? The dynamics of knowledge is increasing. This trend will continue. Next to an increase in dynamics, knowledge will deepen. Specialist professionals will have to be able to keep up with the state-of-the-art in their field. This requires specialist professionals to both be able to handle the dynamics as well as being able to handle the increased depth.

The professional of tomorrow faces a decrease in the half-life of knowledge. In section 3.1 we have discussed this development. This trend can be identified both in the biotechnological sciences as well as in the ICT sciences. The professional also faces an increasing amount of knowledge (Hellawell, 1996). A good example comes from the agriculture sector. With the development of the third stage GM crops a new markets open up. The specific traits of each GM crop have to be genetically engineered. To realise these traits new knowledge has to be generated. As the variety of GM crops increases so does the knowledge regarding these crops increase.

The professional of tomorrow will have to make a choice. The first choice of generalisation has been discussed above, the second choice he has is to specialise in a specific area of expertise. Currently, the professional has a specific spectrum of knowledge that he can handle and keep up with. To be able to keep up with specific developments in a specific area within his spectrum of knowledge requires him to focus his efforts. This focussing results in a narrowing of his spectrum of knowledge resulting in a specialisation.

The choice he will make depends on factors that are uncertain currently. We have shown that several developments will likely sustain over the next ten years. However, some factors will not remain the same, like the organisation of work. A change that may occur in the organisation of work includes the increased mobility of employees induced by developments in ICT. It is these developments that may change over the next ten years that will determine which choice the professional will take. Will he become an expert or a generalist?

A sound analysis of these uncertainties will shed light on the choices professionals will make in the future. The changes in skills are determined by a set of drivers. The uncertain factors are interpreted as drivers whose developments are uncertain a priori. It is then key to estimate the developments of the drivers. By focussing on these drivers an estimation of the choice that the future professional will make, can be made. A scenario is a tool for realising a sound analysis of the uncertain drivers of the future.

Below we discuss two sectors that show in more detail a trend of generalisation on the one hand and a trend of specialisation on the other hand. We show that the developments within each of the economic sectors below can give rise to both generalisation as well as specialisation. We start by describing the effects of the developments in science and technology on the public security sector. We continue to describe the effects of these developments on the health care sector. We end this discussion with the example shown earlier concerning the crops farmer in more detail.

3.3.1 Will the sworn-in officer manage experts or be an expert himself?

The developments in science and technology do not go unnoticed by the criminals (Levy, 2004). A good example is cyber criminals. We will use this example to highlight the developments in the public security sector. With the developments in ICT and of the Internet a new type of criminal has appeared (McAfee, 2005). Several types of cyber criminals can be recognised like those that break into a computer network because they aim for recognition of their peers. Others have more malicious reasons for intruding in a computer system. These intrusions all happen from the comfort of their own home. This is in sharp contrast to the conventional criminal that goes out onto the street and breaks into a house. Today's officer is well equipped to deal with these criminals.

Since the crimes committed require more knowledge, the sworn-in officer has to have a group of experts to support his efforts in upholding justice. The officer can no longer reasonably be expected to be able to know all the details of cyber crime. As the operating systems become more advanced, so does the cyber criminal. Only experts will be able to understand the details of the methods used by the cyber criminal and how he should gather evidence for these types of crimes. However, the experts are not sworn-in and therefore have no authority to prosecute the criminal. It is therefore necessary that the officer work together with an experts or a team of experts to solve the crime.

Thus, the sworn-in officer has to be able to understand and manage the experts that are knowledgeable of the techniques the criminal has used. The officer has to be able to understand what the conclusions are of the investigations done by the cyber forensics. Furthermore, he has to be able to understand the motivations of the cyber forensics to do their work and guide them through their efforts. Although currently these officers already function as a manager for the cyber forensics, this is a relatively new development. These developments will continue in the future requiring the officer to acquire new skills.

In a similar fashion can be argued that the sworn-in officer will have to specialise to be able to solve the highly complex cases. The cyber criminal will keep up with the latest developments. In order to solve the cyber crime committed by the cyber criminal, the legal system will have to keep up with the latest developments as well. While previously the sworn-in officer has to deal with all types of criminal offences, now he has to focus on a specific area of crime. As the crimes get more advanced so do the officers have to become more advanced in order to be able to effectively solve the crime. As the cyber criminal will look for niche opportunities to find a way to enter computer networks, the officers supported by experts have to be able to find and understand the same niches. This will result in highly specialised cyber forensics with specialised sworn-in officers.

Not only does the officer require new skills, the whole legal system, from the officers to the judges needs to acquire new skills. Depending on the exact form of the legal system, the officer presents his case in court. The suspect of the cyber crime has to be able to defend himself by a lawyer who has to be able to understand his client. Furthermore, the judge has to be able to understand what is being put before him. Since the criminals are noticing the developments in science and technology and will learn from them, the legal system has to cope with these knowledgeable criminals. The officers cannot be expected to know everything requiring them to specialise and take up a role of expert manager of cyber forensics familiar with what the criminal knows.

3.3.2 The doctor: manager among experts or expert among experts?

The supervisory surgeon has to be able to switch between various experts. Currently, a surgeon who has climbed up the ranks supervises a set of surgeons. He can therefore easily switch between the surgeons he supervises. In the future this will no longer be the case. The doctors he supervises become more specialised. Their expertise focuses on one area. Consequently not only does the knowledge gap between the various doctors increase, also the gap of knowledge will increase between the supervisor and his employees. A change of skills of the doctors is therefore essential.

The expertise of doctors will be narrower than today leading to a widening of the knowledge gap. Currently, doctors are specialists in a field. Due to developments in science and technology more tools and consequently more curing methodologies will be developed. As each doctor cannot reasonably be expected to know all the methodologies, tools, and techniques in a particular field he has to focus on a specific subset of all the available knowledge and tools. This focussing of knowledge implies a narrowing of the spectrum of knowledge of each doctor.

The increased knowledge gap between the various experts and their supervisors will necessitate a change of skills. The degree of specialisation of doctors will increase. Currently there are a number of doctors in a specific group covering a spectrum of knowledge. When the doctor specialises and the spectrum of knowledge he covers narrows, the full range of knowledge can no longer be covered and gaps will appear. Not only do gaps appear between the various doctors also their knowledge deepens. The supervisor of the doctors with this deepened knowledge can no longer understand them creating another knowledge gap. So not only is there a gap in knowledge between the doctors, also between the doctors and their supervisors is a gap of knowledge.

In the future the supervisor will have to be able to bridge the knowledge gap between the doctors and him. He will only be able to stretch his knowledge over the whole knowledge spectrum when his skills become general of nature. The deepening of knowledge will continue in the future and will widen the two gaps of knowledge. Unless the skills of the supervisor change, these gaps cannot be bridged.

The doctors will have to focus their expertise. Specialists, like surgeons and rheumatologists, used to have the monopoly of knowledge intensive work, like giving advice on medication. Other health care personnel like the nurses, used to provide direct care to the patients before and after their surgery. They provided for the meals and the necessary maintenance of the bed linen and other care, like the administering of medicines in the hospital.

The experts will have to delegate some peripheral tasks to nurses. As the experts will have to put more time into knowledge portfolio maintenance, they will not be able to interact as intensively with the patient as they have traditionally done so. The experts have to be able to keep up with the latest developments in health care. Traditionally the expert, like a rheumatologist, would explain to the patient which medicines to take, the side effect these medicines could have, and how one should deal with ones disease. The nurses will take up this task. Already, the nurse practitioner takes up the responsibility of informing the patient on their medication and side effects (Elizabeth, 2005).

As knowledge becomes more dynamic and the amount of information is rising, professionals in the health care sector will face a choice. They can either generalise or specialise. When specialists become more specialised their managers can either follow and specialise as well or become generalists. The nurses that help the specialists will have to take up some of their responsibility.

3.3.3 The farmer as a rural businessman or a agricultural expert?

The farmer of the future may resemble a corporate businessman more than he does today. New markets will appear in the future as a consequence of the third stage developments in GM crops. Currently, the second stage of the biotechnological developments in genetically modified crops is under way. The first stage of developments focussed on the realisation of crops with traits beneficial for the farmer, like pest resistant crops. The second stage in the developments in GM crops focuses on providing crops with traits beneficial for the end-consumer, like nutritional value. Another example of a second stage GM crop is a high oleic soybean. The third stage will focus on using GM crops as factories enabling them to produce goods for other industries like the pharmaceutical industry. The third stage developments will open up a whole new market.

The broadening of the market for the farmer will open up niche markets allowing a better crops-portfolio management. As more industrial markets, like the pharmaceutical industry, open up the farmer can produce an increasing amount of different product. Although various crops are already being produced next to each other, this crops-portfolio management will be more elaborate in the future (USDoL, 2004).

The rural businessman has to be able to analyse its market. The increasing dynamics of knowledge will lead to an ever rapidly changing supply of GM crop varieties. Furthermore other factors that influence the farmer, such as land prices become more liquid. The increase in information will allow the rural businessman to find the latest relevant information, like a new crop variety. With all this rapidly changing information it is crucial that the rural businessman will be able to make strategic decisions concerning his farm in particular on property acquisition and financial issues. With the increasing liquidity of the factors affecting the farm the farmer will have to be able to analyse these factors.

The farmer may have to become a generalist. The increasing liquidity of the factors affecting the farm may prove to be difficult for the farmer to cope with. It will require him to be able to understand the broader scope in which his farm is producing crops. This broader view will require him to become more of a generalist than he is now. He will have to broaden his spectrum of knowledge.

Similarly, today's farmer can turn into a rural expert of the future. The crops market will become more liquid. Additionally other factors determining the success of the crops farm will become more volatile. Facing these challenges the farmer has to be able to analyse the developments that are relevant for his farm. The developments relevant for his farm are determined by the variety of crops he grows. As he has to specialise to be able to keep up with the crop varieties on the market, he has to specialise in order to be able to make long-term decisions for his farm. The present day farmer may become a rural expert.

Sometimes the size of the crops farm does not allow a separation of specialisation and generalisation. The size of the farm often determines which tasks the farmer himself performs. In the US the majority of farms are small and consequently the farmer does all tasks, such as physical and administration tasks (USDoL, 2004). Operators of large farms can delegate these tasks to employees giving them more opportunities to have all the required knowledge in house.

Intermediaries may provide the knowledge intensive tasks required for the farm to be able to survive when the knowledge cannot be kept in house. Currently there are already extension services that provide these services. The extension services provide a link between the research base and the farmer. They distribute the knowledge generated there to the different farmers. The intermediaries will provide sufficient knowledge for the average farmer who has been trained through vocational training.

4. Range in future professions

4.1 Probing the future

As we have seen in the previous chapter, the science and technology (S&T) dimension in professions is increasing and this may lead to a different set of skills required to perform jobs in the future. The four case studies demonstrate that S&T developments affect economic activities and change the professional skills required for these. They also indicate that in different sectors other drivers than S&T development, such as work organisation, play an important role. However, the development of these "drivers" over time is not yet certain, as demonstrated by the question whether generalisation or specialisation is required, which is the reason why we chose to construct a set of scenarios to probe future possibilities.

The scenarios aim to identify possible directions that professions may take as a response to changing conditions in the S&T and organisational environment; these directions may determine the need for higher education/research curricula and thus suggest policies on how to adapt the current structures to the differing circumstances in the next ten years. It is important to note that the most important outcome of such an exercise is not the scenarios themselves, but the discussion that emerges as a result of doing a scenario exercise. In this project we have used scenarios to describe possible future professions in the four economic sectors; the scenarios and the professions were used in a workshop.

Ideally, the different foci of the developments in the sectors will cross-fertilise the discussion and lead to certain insights and policy responses that can be generalised. However, it may still be the case that the same types of developments will lead to different educational approaches in different sectors.

4.1.1 Selecting drivers, building scenarios

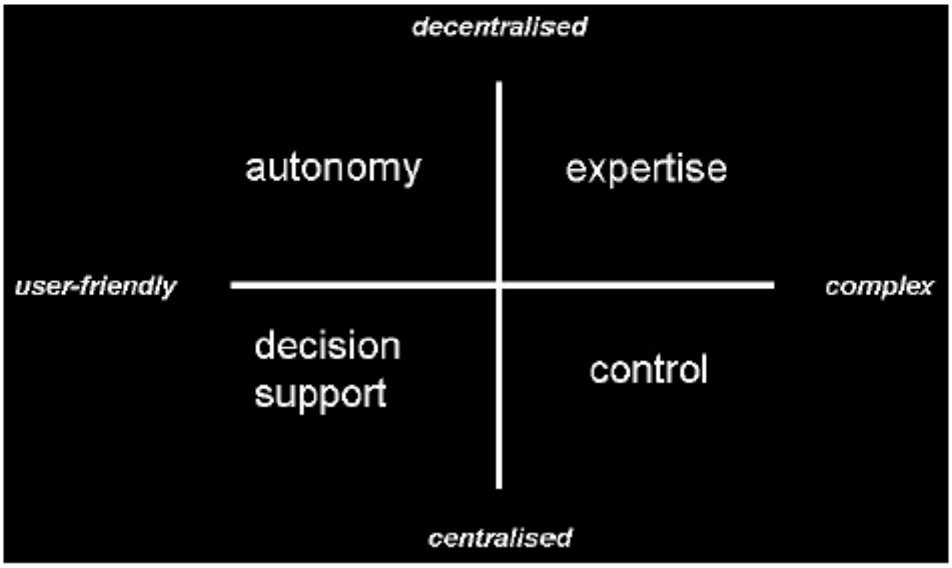
Building scenarios depends on identifying drivers that have a high impact on the topic, but are at the same time uncertain. Based on our analysis of developments in S&T, work and education (Chapter 2) as well as the four economic sectors and the developments that take place in associated professions (Chapter 3), we have identified two main dimensions that will alter professions in the coming years, but are not a certainty. The first dimension relates to the development of science and technology, which after all is the main topic of the report. However, differentiating e.g. between a high-tech and low-tech future would not lead to relevant outcomes for this project (assuming that in a low-tech scenario, educational practices would have to change less). The second dimension needed to be work-related, as we concluded above that factors other than S&T play an important role in professions' development. Therefore, we have selected the following dimensions as most relevant for constructing scenarios:

- High/low user-friendliness of technologies: in this project we assume that science and technological development will continue to evolve in the foreseeable future and thus the amount of technology and knowledge required to perform a job according to the standards of that moment will increase too. What remains unclear, however, is whether the technologies that are developed will become easier to handle, more user-friendly. For example, developments in cognitive science may lead to better understanding how human thought-processes work. Conversely, technologies may require additional knowledge; not only of devices, machines, implements and instruments (hard technology), but also of (management) skills and the surrounding system (soft technology). User-friendliness will influence the acceptance and adoption of new technologies and the skills required for handling the technologies involved. Generally, a user-friendly technology will need to be designed with the demands and working conditions of the end-user in mind: it will need to be built upon the knowledge of the work process the technology is aimed to support (e.g. in life and death situations in hospitals there is less tolerance for failure than in e.g. crop sensors). Some complex S&T developments may remain complex (such as laboratory work), whereas others will become less complex (such as specific in-the-field sensors).

- Increased/decreased centralisation: in some instances, a response to increased pressure and workload, e.g. due to an increase in demand for specific professionals, could be to decentralize responsibilities and delegate to other practitioners in the organization. Another way of responding would be tighter control on workflows and centralized responsibility. Technology can support both centralization and decentralization of responsibilities and thus this can be seen as an independent development. In chapter 2 we already suggested that technology may lead to Taylorisation (extreme specialisation, often associated with assembly lines and manual labour). On the other hand, technology may support more autonomous decision-making within a certain boundary (e.g. nurses making decisions on emergency cases), increasing or at least changing the current responsibilities of the workers. The choice whether to opt for more or less decentralised decision-making is to some extent a function of the working environment thus this is a situation that may differ per sector and per job.

Combining these two drivers leads to a classical scenario-framework with four quadrants, each constituting a different scenario. Each scenario text was written to include elements of technology, economy, legal issues, organisational issues and national/European orientation. They were also given a name that represents the relationship between work and technology: autonomy, control, decision support and expertise (see Figure 7). The scenario texts are included in Annex E-H; the salient elements of these scenarios are included below.

Figure 7: the names of the four scenarios that were used in this project, based on level of centralisation and user-friendliness of technologies



4.2 Four scenarios

For each of the four scenarios constructed, we selected those elements that constitute a dominant work ethic or relationship between S&T and professions (which is reflected by the names). The effects on several professions in each scenario are described below. It is important to point out that these scenarios are not mutually exclusive, but rather represent different developments that could take place in different European regions.

4.2.1 Autonomy

Autonomy in the workforce entails an element of self-organisation in complex organisations, which implies adherence to professional standards, or a broadening of the knowledge to apply in different realms, creativity to seize opportunities or to solve problems.

The autonomous nature of work is clearly visible in the healthcare sector: due to increased pressures with regard to the lack of healthcare professionals as well as a higher demand for services in this sector, nurses are given autonomy in diagnosing illnesses and deciding on treatments (e.g. nurse prescribing provision of home care technology for intravenous treatment of AIDS patients) with the help of appropriate voice-guided decision support systems. Clearly, from the part of nurses, this requires taking initiative, making decisions and taking responsibility, even though they may receive some help through electronic guidelines. This may require additional training in using the technical support tools, but more importantly would require an adjustment in the organisational setting of the hospital. Additional skills required may involve handling this new role in quite rigid organisations.

Farmers are also supported by information systems that provide help in making operational decisions. Sensors connected to expert systems help decide when is the best time to sow or harvest crops. Also, these expert systems help the farmers to plan crop rotation schemes. Stronger crops are available that are easier to handle while improved machinery such as robots help in watering plants and harvesting them. With some of the operational decision making supported by new technologies, farmers may concentrate on more creative aspects of their trade: business skills to position themselves more optimally in the market and seeking niches in which specialised crops may yield better returns. They may decide (or be required by the business margins) to take on broader activities such as environmental protection tasks (e.g. friendly ploughing schemes or maintaining broader margins at the edges of the field to allow wildlife to grow), schooling and informing activities, or agro-tourism.

In handling freight, advanced information systems help transporters pick and choose and plan in advance what freights are going to be transported by what party. By opening up their individual planning systems and simultaneously granting access to their own systems to partners, the network of handlers and transporters can optimise the flow of goods. For many routine activities, this will be handled quite efficiently by automated systems, but for special deliveries and out-of-the-ordinary freight, a more specialist and thus personal approach would be required. This professional would need to know how to integrate these special deliveries into the regular flow of goods.

4.2.2 Decision support

Jobs that occur in a decision support scenario are facilitated, on the one hand, by technologies that are tailor-made to fit the context of that job; on the other hand, they are supported by strict guidelines that prescribe actions to be undertaken (these guidelines are often embedded in the software or technology that is used). This may make professionals' jobs easier, but will also allow a broader range of activities to be undertaken by the same people.

The increased focus on security & control has led to a higher demand for all kinds of controllers of processes. These controllers have access to a broad range of sensors for monitoring the environment: security officers, guards, and customs officers, for instance, monitor baggage-scans and security cameras. These scans and monitors are supported by artificial intelligence that helps recognise patterns that are 'out of the ordinary'. The job of security guard has become easier with the increased use of the technological support – this has led also to the increase of the number of items that can be monitored by one person. Instead of on the ground security many companies rely on off-site monitoring of cameras and sensors.

Physicians are aided in their work by systems that rely on an Electronic Patient Record – thus all data that is recorded on a patient is immediately cross-checked against historical data in order to recognise patterns in the evolution of their health condition. Measurements are made with the help of sensors that are worn in 'smart' t-shirts. Based on the readings, a decision-support system helps physicians to design the appropriate treatment taking into consideration the latest evidence-based medical knowledge. This links quite closely to other trends in healthcare practice, in which the doctor operates less as 'expert' and more as 'coach'.

Dockhands and farm labourers are aided in their work as they receive instructions based on computer-aided process control – this ensures that the activities on the work floor take place in a coordinated fashion. In case the instructions require difficult procedures or technologies, the workers can wear AR-goggles or receive spoken (computer-generated) instructions. Thus, on-the-job training can take place.

4.2.3 Control

The control character of this scenario will require specialists to have a deep knowledge of the technologies that they are handling, as well as of the influence that these technologies have on the wider system (value chain) surrounding the professionals: it requires insight in the factors that control their environment as well as the factors that they control.

In farms operations, an element of systemic control would be a tightly controlled (legal) environment due to a range of environmental regulations (both for agriculture and animal husbandry, as well as all kinds of regulations regarding their produce and their interaction with the natural habitat). These regulations require farmers to be more tightly in charge of the inputs and outputs of their activities, which would require e.g. knowledge about the use of (bio)sensors and how to analyse the data acquired by these sensors. This would have to be translated into assessments whether critical values are reached and what mitigatory measures should be taken to harness potentially damaging activities. It would require farmers to be more knowledgeable about (basic) biochemistry, sensor technology, data analysis and legal requirements. The productivity of farm hands may be more tightly controlled and targets may be set based on benchmarking data.

In public safety and especially in forensics, there is a whole range of specialists that perform specific analyses using a range of material biotechnological sciences, such as DNA-analysis through labs-on-chips. For these analyses they require an advanced level of scientific knowledge. The control element in their work could encompass the fact that they perform these analyses based on a set of rules and tools, so that their interoperability across departments or precincts is safeguarded. Also for this group of specialists a tight control of work activities through daily targets is conceivable – the timeliness of their analyses is crucial for a swift and efficient handling of cases, thus these activities are prone to be high on deadlines. Luckily, much of the bio-analysis would be supported with the help of analytical robots, which require special training to operate. To ensure fruitful collaboration with the detectives, this work may also require an intermediary generalist who understands the needs and requirements of both the laboratory requirements as well as the policing side.

For freight handling, there is a need for highly trained systems architects and analysts who control logistical flows on sites such as harbours or container terminals. These specialists need a broad overview of how the system works and how the freight in the port is received from one agent and transferred to the other. These controllers receive support from large amounts of sensory data (e.g. RFID-tagged containers) and management information systems; they depend to a large extent on their expertise to improve and 'tweak' the system. They control labourers' operations and determine the daily activities of the workforce. Again, some of the handling activity may be supported by robots that are centrally guided. Workfloor activity may thus be limited to operators who make sure that no accidents happen.

4.2.4 Expertise

The essence of professionals in this scenario is that they require a large amount of knowledge to effectively work in their organisations; furthermore, this knowledge needs regular updating as the half-life of knowledge decreases. Not only are these experts required to know a lot about technical issues, but also organisational and legal issues, which allows them to work efficiently and effectively in a decentralised setting.

In the agriculture sector, processes have become high-tech, both in the field as well as in the whole organisational chain. Technology for sowing, reaping and handling grain becomes more complex as well as all regulations that address environment and food safety. Farmers need to acquire additional knowledge on how to manage their own activities while at the same time responding flexibly to their customers. Although a PhD is still not required to farm, farmers do rely increasingly on experts that help them tighten their control of processes and increase efficiency, maintain their technologies, and plan their activities and liaise with customers.

Healthcare professionals are confronted with a whole range of new technologies that require detailed knowledge. These are for instance food & health advisors, that can utilise the data from sensors and labs-on-chips to devise physical exercise and dietary regimes for their clients. In the hospital, specialised multi-trauma doctors rely heavily on robotic assistance so that they can perform new micro-surgical operations that were previously impossible.

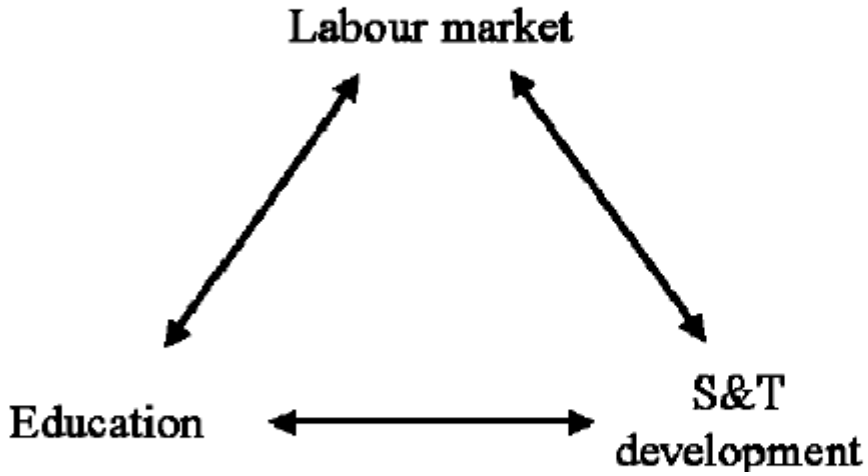
In the public safety sector, forensic specialists continue to expand their analytical toolkit; the use of their chemical and biological sensors as well as the analysis of the data acquired from the field require a high degree of specialisation that evolves towards the cutting edge of their field. The access to databanks and the information stored therein requires advanced search & retrieval techniques that are performed by data-technicians.

4.3 Underlying issues in the future of professions

4.3.1 S&T and adoption in the labour force

Although science and technology developments have an impact on the labour market, they cannot be regarded solely as drivers: in the labour market system we find a process of co-evolution and thus clear cause and effect is not present. Therefore, our understanding is that S&T developments, labour market and education are mutually dependent and influence each other constantly. This is depicted in the figure below:

Figure 8: Labour market, education and S&T influence each other



The 'success' of a technology is dependent on its user-friendliness: technology needs to be(come) user friendly in order to become pervasive. As such, it is difficult to anticipate a technology with a low extent of user-friendliness making a huge impact on a wide range of professions. Although systems are becoming increasingly complex, the development of these technological systems will need to be paired with an effort to make them easy to use. Design plays an important role in this respect. Nevertheless, even designing user-friendly technologies does not automatically lead to success. New technologies can only become pervasive when they are absorbed and learned, which requires investments, both in terms of finances and time.
ICT allows for a complete new way of processing knowledge. This is why it has such an effect on professional requirements. However, depending on the economic sector, other developments are relevant as well, and may be more important than ICT. As such, ICT may be too broad a category to take into consideration; rather, in future research activities it should be seen as a conditio sine qua non.

4.3.2 The impact of globalisation

The scenarios touched on the development of globalisation and internationalisation. However, the international component of knowledge is not new: already in the sixteenth century there was the international distribution of knowledge as shown by the work of Galilei. Currently, the means of transportation and communication have allowed an intensification of international collaboration. However, the trend that is currently observed may not sustain.

The past has shown that many breakthroughs in science have been induced by a shift in paradigms. An illustrative example in this context is the discovery that the earth circles the sun and it is not the sun that circles the earth. This shift in paradigm had a profound effect on society as a whole. Since the earth was no longer the centre of the universe the self-image of men changed as well and some of the catholic doctrines were questioned. This questioning caused a breakthrough in science and many other areas in society.

Breakthroughs in science often came from interdisciplinary efforts. Two examples are illustrative. Galilei was a supporter of Copernicus' heliocentric model of the solar system. His work on experimental physics was innovative. However, he made use of standard mathematical tools. This new application of well known mathematical methods also appears in the paradigm shift from the Maxwellian electromagnetic worldview and the Einsteinian Relativistic worldview. Einstein made use of well-known mathematics that was not used in physics yet to set up his theory of general relativity.

4.4 Similarities and differences in the range of future professions

The differences in scenarios remain difficult to compare. However, some observations may still be drawn from the descriptions given above:

- As in each scenario technology develops further, there will be a need for professionals who provide services or supportive jobs to maintain technologies that are used in a specific sector; these professionals would require a multidisciplinary background, or at least they require both insight in the sector as well as in the technologies used; the design of user friendly systems would require knowledge of technology, ergonomics and business processes; likewise, the development of control systems requires knowledge of technology, organisational flows, and legal restrictions.
- This issue of specialisation or generalisation seems linked closer to the issue of centralisation than to the issue of S&T development. As indicated before, technology can support both directions. In each scenario both specialisation and generalisation can take place, be it in different degrees.
- The more complex the technology, the more need for life long learning (LLL); given the decreasing halftime of knowledge, professionals may have already lost their state-of-the-art knowledge by the time they have been working a few years; it is therefore very questionable to teach specific technologies in detail – part of the technology knowledge uptake may be more efficient in workplace settings.
- Expertise or excellence in non-technological subjects becomes more important in all scenarios: business skills, creativity, systems analysis, organisational understanding, legal skills, negotiation skills etc. Depending on the dominant characteristic of the scenario, some of these skills are be more important than others.
- Once again we would like to emphasise that the different scenarios can coexist across regions, as different clusters of organisations may attempt to tackle the issues of centralisation and uptake of user-friendly technology differently; theoretically, even the scenarios may coexist within sectors, as one group of professions might tend towards centralised steering whereas the other group may be more decentrally managed. Given this remark, we admit that there is not one clear strategy that an employee could follow in order to improve his/her chances on the job market, except for clearly analysing what type of persons are needed and improving their personal skills to match the needs of the market or seek a different market. Conversely, an employer (or branch

organisation) would need to regularly clarify what his needs with regard to employees' skills are.

- In all scenarios, there is always a need for proverbial sheep with five legs. In other words: as long as the knowledge society develops, acquiring more knowledge and skills will remain a good strategy for most citizens.

5. Discussion and research roadmap

What are the changes to the education system, training practices and human resource strategies that need to be implemented in the coming years to prepare for future changes in professions? Unfortunately, this research question cannot be answered in a simple fashion. However, this project has yielded some additional insights that may help build the case for issues such as: alignment and cooperation of various players, and the adaptability of employees. Furthermore, some questions need to be resolved with regard to investment in life long learning and proper regulatory instruments. Finally, some suggestions for further research at the sector level are made, as the topic is too broad to study at a general level.

5.1 What needs to be accomplished?

5.1.1 Alignment of players

One of the clear outcomes of this project is that the idea of technology push is to be rejected: although at times science and technology seem to be independently driving the developments in society, they are themselves dependent on forces in both the labour market (organisations, businesses) as well as in the educational system. A technology that is neither adopted by enterprises nor taught in schools looses its significance. Educational institutions are constantly reminded that they need to take into consideration the requirements of the job market as well as new scientific developments, while at the same time teaching basic skills and basic knowledge that is the foundation for further development. Enterprises consider skills needs and determine their skills strategies (hire workers with the right skills or train them in-house), while at the same time attempting to influence research and development towards most promising directions.

Further enquiries into this field will have to engage with (representatives of) all three groups of players (education, market and S&T), taking into consideration the fact that changes in each of these systems take time. The use of technology is embedded in organisational structure, which takes time and effort (and thus investments) to change. In the race towards value creation through innovation, it should be noticed that a certain lag in response time creates stability for the players involved[4]. In order to achieve balanced development, regular dialogues between the players seem appropriate. These dialogues could take place in the shape of future scenario or foresight exercises. Nevertheless, in dynamic times professionals need to be prepared to adapt to new situations.

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[4] *Although often used in a positive connotation, Schumpeter's creative destruction involves destroying certainties as well as previous investments.*

5.1.2 Teaching adaptability

Knowledge will become more ephemeral than it is today. As a result, it will be necessary to focus on teaching generic techniques as well as teaching specific knowledge. In the future, the success of an economic sector will lie in its ability to restructure itself quickly; the labour force needs to adapt to these changes as well: they will more often switch jobs or will be placed in a completely different position. Therefore, part of the workforce will have to learn to adapt to new environments. This skill is closely linked to the famous "learning how to learn". It is, however, not clear which employees should be most adaptable and how this skill should be taught. As of yet there are no clear indicators that can identify this "adaptability" skill.

As it is currently not clear how to learn the skill of adaptability, it is important to first get a good understanding of this skill before measures are taken to improve the educational structures within the EU. Better understanding may be achieved by designing some tests about the adaptability of the workforce. These trials could involve, for example, nurses that are primarily trained on the job and other nurses that are trained by conventional methods. Then after three years, their adaptability could be measured and a distinction between the two methods of training may surface. For each of the four case studies of this report, we describe some research suggestions in the final section.

5.1.3 Learning from other countries

Not reinventing the wheel is a sane strategy. Especially new member states have the possibility of leapfrogging developments that have taken the old member states decades to achieve. There are several factors that enhance the possibility that leapfrogging is a viable option: a) in new member states the status of science and technology is often high, sometimes higher than in old member states, and b) new member states have a greater capacity for experimentation as they have and still are going through the process of renewing systems and structures. A case in point is Slovakia's relatively smooth adoption of a national electronic patient record system, whereas a country such as The Netherlands remains entrenched in political and organisational struggles that have already taken more than 20 years (PRISMA, 2003).

EU Member States will need to focus their efforts to achieve globally. This conclusion is also supported by foresight studies on the agri-food sector. Naturally, the EU Member states differ and the EU should recognise these differences and capitalise on them. Without EU coordination this may prove to be difficult. The different Member States should combine their policies to cover a significant spectrum of activities and at the same time aspire to excel. In other words: the spectrum of excellence of the EU can only have a maximum width if the national efforts are coordinated.

5.2 Challenges and knowledge gaps

5.2.1 Investing in life long learning

Life long learning is a well-known European adagio to update and upgrade knowledge and skills throughout a person's lifetime. Generally, this notion is not challenged, as most people cannot expect their knowledge to last a lifetime. However, the issue of "who pays for what" remains unsolved.

There are generally three sources for investing in knowledge; society, firms, or students pay for education. Currently, most funding in Europe is provided by society. There are, however, a number of reasons that favour a combined approach of funding. Investing in knowledge is like any other investment and has a clear and well-defined lifespan. It is therefore not immediately clear that society needs to pay for education. It is also not clear whether society gets its investment back, by, for example, taxes, and better overall economic performance. Therefore, it is quite defendable that society should not provide for too specialised education. Firms already pay for the education that is needed to performing well for a specific job and individuals always have the opportunity to expand their knowledge based on their own means. Depending on the type of skills that are taught and at what stage in a person's lifetime they are taught, society, the firm, or the student should pay. As already indicated above, dialogue between the different players is important, also concerning this issue.

As the developments and rate of change in developments is higher than before, life long learning becomes ever more important. However, firms may not make the necessary investments. Due to the decrease of the half-life of knowledge, it is important to change the focus of learning more to methods that teach how to learn. One example of such "meta-learning skills" is problem-solving skills. By learning how to learn, it is easier for a person to learn new skills and therefore be more adaptable, an issue that is discussed below. By knowing how to learn a person can thus keep up with all the new developments and will be able to benefit from these new technologies.

5.2.2 Professional requirements

Currently, the emphasis of EU education regulation concerns the completion of training, while it should also address the maintenance of portfolio of the workforce. In France, for example, there is legislation on life long learning that requires companies to invest in the maintenance of the portfolio of their employees by at least 1% of their total annual income. This could be promoted by various DGs in Brussels for their respective fields of activity.

Regulation can have a major impact on the skill change of various professions. An example comes from the agriculture sector where regulation imposed the farmer to test their products themselves. This required the farmer to learn the techniques to do these measurements and as a result acquired new and different skills. This shows that direct requirements to professions may not be necessary, but may be imposed by changes in the legislatory or organisational environment.

5.2.3 Mobility and recognition of knowledge

Mobility is still increasing in its importance. With more specialisation, fewer people can be serviced by one specialist, which either leads to increased pressure for the existing specialists or an increased demand for specialists. This will increase the demand for mobility; experience has shown that ICT can only partially respond to the need for mobility.

To promote mobility it is essential that degrees are acknowledged throughout the EU Member states. Currently, such a system is only partially in place. Although the Bologna process moves in the direction of comparability, it is not yet very extensive. The question is whether the EU should have a role in determining the content of curricula. It can, however, have a role in the educational structures within the EU. If any form of quality assurance should be adopted, it should only regard the methodologies of education and not its content. The educational structure should be appropriate for an environment where the rate of change in R&D developments is high and the half-life of knowledge has decreased considerably over the last 50 years.

5.3 Defining promising pathways

Our study of the training and educational needs of professions has shown that the time is not yet ripe for firm recommendations on what is needed. This is because of two characteristics of the professions we studied. First, the changes brought about by science and technology developments will differ according to the specialisation level of the professional; our case studies showed that while the "second tier" of expertise will need to adapt, the other tiers depend on the substantive area. The other characteristic is that, for all of the professions, some form of "learning how to learn" appears to be needed, and how this can best be done is not yet fully known. To these characteristics, we add that professions are not evenly developed across Member States, so that even though a future high level of performance across professionals in all Member States is very much desirable, the type of education needed to bring all European professionals to a comparable high level of performance may not be the same in each locale.

For example, we did find that in health care delivery, nurses will have to be more proficient at information technology tasks, both in using the technology to rapidly understand a patient's situation and in data entry so that the entire health care team can benefit from the observations and interventions. While some of this proficiency can possibly be trained in traditional reading, lecture and drill methods, it is entirely likely that some of the proficiency can only be gained via simulated use of the tools that the nurses (will) have available. To better understand training needs, studies comparing traditional and experiential learning for this class of professional are needed. While such experimental studies are typically not funded directly from European sources, DG Research, working with DG SANCO can serve a useful purpose in helping design and partially funding an extensive study of this type that varies across and within Member States.

A second example could be a study of how different possible organisational structures that explicitly incorporating generalists as knowledge managers can help the agricultural sector better exploit the scientific and technological advantages in biosciences. Here, different structures in comparable regions and Member States can be established, and measurement can be made from the agricultural professionals' point of view of how this affects what they know and how they use their knowledge. "Best practices" can be developed in such an experimental design that can lead to timely exploitation of knowledge. (Note that this is NOT a study of the use of ICT, but rather of how to disseminate more disciplinary knowledge through better understanding of how specialisation works in the knowledge society.)

Public safety, more than the other professions, has incorporated experiential learning tools, at least at some national levels (e.g., the Netherlands, UK). For this professional area, the unknowns are how well the learning tools transfer across cultures and across professional levels. Thus, for example, police in the Netherlands regularly undergo experiential training in learning how to manage potentially violent situations, police in other countries might or might not benefit from adapting the Dutch techniques. Moreover, once police have advanced from the field to more administrative jobs--even in the Netherlands--these tools are not used for ongoing management. The increasing sophistication of simulation techniques needs to be better understood and supported across the EU, and this is an unrecognised priority that DG Research can help foster.

The example posed above for public safety gets reversed when transport professionals are considered. In transport, there have been extensive models used and employed by the highest level of professional, but the dissemination of adaptive learning down to the lower professional levels has been less developed. How tools useful at the policy level can be modified for use at the implementation level remains the challenge here, and could be the subject of useful experimental studies that could be coordinated across countries by DG TREN and DG Research.

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