# ANALYZING FORESIGHT STUDIES IN CONVERGING TECHNOLOGIES STUDIES OF EU, USA AND TURKEY

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Approval of the Graduate School of Social Sciences

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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## *ABSTRACT*

ANALYZING FORESIGHT STUDIES IN CONVERGING TECHNOLOGIES STUDIES OF EU, USA AND TURKEY

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The aim of this study is to examine the situation of converging technologies - nano technology, biotechnology, information technologies, and cognitive science - in Turkish foresight study and to analyze situation of Turkey.

The research on convergence in Turkish foresight is carried out in the first foresight study of Turkey, Vision2023 consisting of Delphi Report, Panel Reports and Strategy Reports. All of these reports are investigated thoroughly to find out the statements about the converging technologies to have an insight what Turkey is planning to do in the following years. Additionally, to compare the perspective of Turkey in terms of converging technologies, the findings of this study are compared with the findings of the USA NBIC Report. Moreover, as a base of comparison of findings, the foresight study (ManVis Study) whose participants was 22 European

countries one of which is Turkey about manufacture vision is taken into consideration.

The findings of the study indicate that in different reports, there are some visions that are not mentioned in Vision2023 Study. A detailed investigation of these, shows that most of these visions are related to cognitive science. Only a few are nano technology oriented visions. However, according to the findings of the study, in biotechnology related statements, the position of Turkey and expertise of Turkish scientists are considered as “very good” by Turkish experts. As far as information technology in Turkey is considered, Turkey is in an average position among other countries according to the findings of the study.

Keyword: Nanotechnology, Biotechnology, Information technology, Cognitive science, Converging technologies, Foresight, Vision2023, NBIC, ManVis.

# *ÖZ*


AB, ABD VE TÜRKİYE'NİN YÖNDEŞ TEKNOLOJİLER ALANINDAKİ ÖNGÖRÜLERİNİN ANALİZİ

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Bu çalışmanın amacı yöndeş teknolojiler alanında – nanoteknoloji, biyoteknoloji, iletişim teknolojileri ve bilişsel bilimler - Türkiye'nin öngörü çalışmasını incelemek ve Türkiye'nin durumunu analiz etmektir.

Yöndeş teknolojiler alanında Türkiye'nin öngörüsü Türkiye'nin ilk öngörü çalışması olan Delfi Raporları, Panel Raporları ve Strateji Raporu kapsayan Vizyon2023 çalışması üzerinden incelenmiştir. Tüm raporlar Türkiye'nin önümüzdeki yıllarda yöndeş teknolojiler konusunda neler planladığını anlamak için incelendi. Buna ek olarak, Türkiye'nin yöndeş teknolojiler alanında bakış açısını karşılaştırabilmek için ABD'nin NBIC Raporu incelendi. Bundan başka, sonuçların karşılaştırılmasına taban oluşturması için Türkiye'nin de içinde bulunduğu 22 Avrupa ülkesinin üretim

teknolojileri alnında yaptıkları öngörü çalışması (ManVis Çalışması) dikkate alındı.

Sonuçlara göre yabancı öngörü çalışmalarındaki bir çok konu başlığının ve teknolojik öngörünün Vizyon2023'de bulunmadığı anlaşılmıştır. Detaylı bir araştırma bu vizyonların çoğunun bilişsel bilimlerle ilgili olduğunu gösterdi. Bunun dışında birkaç tanesi de nanoteknolojiye yönelik vizyonlardır. Buna karşın, sonuçlara göre Türk uzmanlar, biyoteknoloji ile ilgili konularda Türkiye'nin durumu ve Türk bilginlerin uzmanlık durumlarının iyi olduğunu düşünmektedir. İletişim teknolojisi göz önüne alındığında ve diğer ülkelerle karşılaştırıldığında orta sıralarda yer almaktadır.

Anahtar Kelimeler: Nanoteknoloji, Biyoteknoloji, İletişim teknoloji, Bilişsel bilimler, Yöndeş teknolojiler, Öngörü, Vision2023, NBIC, ManVis.

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# *CHAPTER 1*

## *INTRODUCTION*

The gap between rich and poor countries remains one of the most challenging problems faced by the economics circles. In fact, it is widely accepted by economists from different approaches that there is a strong relation between the increase in new products, evolution in their production methods and developed production techniques of other sectors, as well as spread of these products, methods and techniques, and spread of all these into the entire economic system in which they are produced.

Neo-classical and evolutionary theories have been examining factors in the formation of the technology and innovation policies at national levels. Evolution in technological systems creates long-term results that can have a deep impact on economic systems. To illustrate, the invention of steam and electric power in the past, and recent innovations in Information Communication Technologies (ICTs) field have had significant impact on living and working conditions and technological progress.

On the other hand, the economic value, environmental impact and social utility of newly developed technologies are uncertain. Those who plan to engage themselves in those areas should consider the probable development for one or two decades. Hariolf Grupp and Harold A. Linstone claim that depending on action or non-action at present, many futures are possible, but only one of them will happen (1999). Moreover, Ben Martin attracts the attention to the impossibility of supporting all areas of science and technology (1997), indicating that it is necessary to create a critical vision, leading to the idea that foresight becomes an important issue.

To build a more predictable future, decision makers have to create wombs for infant technologies or even force some technologies to work with others combining their power. The followings are the most representative examples of the idea mentioned above: An innovation in nanotechnology enables biotechnology to create new imaging technologies; solving secrets of DNA gives a new vision to information technology; studies on computer language manipulates learning concept in cognitive science. Such technologies that enable each other are called 'converging technologies'. This interdependence indicates that the future of development is closely related to the successful application of such an integration process. In other words, those countries which are successful in the application of this process will be the ones leading the developments in the future. Therefore, understanding where Turkey is in this process may be important to assess its role as an actor in development in future.

In this thesis, foresight studies of the USA, as the leading actor of such studies, and Turkey on converging technologies are examined, and their results are compared to have an idea about the place of converging technologies in Turkey's national foresight. Moreover, the results will be compared to the results of foresight study of a group of European countries to understand the relative position of Turkey among those countries.

The first chapter of this thesis is about the aim of the study, and the method that is used in comparing these foresights; the second chapter briefly reviews the literature in foresight and converging technologies; the third summarizes the foresight studies of the USA, EU, and Turkey in this field; the fourth shows similarities and differences between the results of the foresight study in the USA and Turkey and EU and Turkey; and the fifth one is devoted to the discussion the results.

### *1.1. Aim of Study and Method*

The aim of the study is to examine the situation of converging technologies - nano technology, biotechnology, information technologies, and cognitive science - in Turkish foresight study and to analyze situation of Turkey.

In order to understand the concept of converging technologies in the foresight perspective, American, Canadian, and European foresight reports on converging technologies are examined, and The American NBIC Report is taken as a base for comparison since it is the first foresight report that covers these technologies with a foresight perspective and since the other two studies have very similar points with it. The Canadian Bio-Systemics Synthesis (2003) is the second study that focuses on converging technologies in foresight concept. However, Canadian Report is a biotechnology centered study. The EU has prepared four reports that cover each one of the converging technologies and a report that specially examines the converging technologies. Reports about each converging technologies are prepared by the expert groups of each field and named as Key Technologies Report. In each report, convergence with the other technologies is mentioned. Moreover, in Converging Technologies – Shaping the Future of European Societies Report, convergence is examined in detail. Both Canadian and EU Reports are significantly influenced by the NBIC Report which is the first study on converging technologies.

The research on convergence in Turkish foresight is carried out in the first foresight study of Turkey, Vision2023 consisting of four main reports. Among those, three of them: Delphi Report, Panel Reports and Strategy Reports are investigated thoroughly to find out the statements about the converging technologies since only these three reports includes relevant data for this thesis. The situation of Turkey on converging technologies is analyzed to specify and eliminate the drawbacks of Vision2023 statements which are not based on a specific foresight study on converging technologies.

In order to compare the situation of Turkey in terms of converging technologies, foresight study that is global or is prepared and done more than one country is required. However there is no global foresight study about converging technologies moreover there is no foresight study about converging technologies that is done by more than one country. On the other hand, there is a foresight study that has participant of 22 European countries which one of them is Turkey about manufacture vision. Statements about converging technologies in this study are determined to compare the situation of Turkey.

## *CHAPTER 2*

## *SHORT HISTORY OF FORESIGHT*

Technology forecasting first came to eminence in the late 1950s in the United States defense sector (Pill, 1971, p. 58). Delphi questionnaire survey, which is developed by Helmer and colleagues to seek the opinions on atomic warfare (Pill, 1971). Large-scale forecasting studies were carried out during the 1960s by the US Navy and by the US Air Force (Pill, 1971). First non-military application suggestion that recommend using foresight in planning developing economies was proposed by Helmer in 1963 (Pill, 1971, p. 58). Technology forecasting was taken up by private companies; for instance, Shell's foresight programme in the early 1970s prepared it for the oil shocks of the time (http://www.ncvo-vol.org.uk/vsmagazine/features/index.asp?id=1858). However, the following developments, and the emergence of what is understood with the term 'foresight' today, took place in Japan, and in every five years there is a national foresight study in Japan (Grupp and Linstone, 1998). National foresight studies have been the key social innovation to satisfy the need of a long-term perspective. Started off as 'science and technology' foresight in Japan in early 1970's, this first generation foresight was translated into German and replicated (Grupp and Linstone, 1998). In addition to replication, further developments occurred in European countries as a notion of 'foresight' covering all areas including society and culture according to their national structure in the 1990's. This led to foresight programmes in the UK, the Netherlands, Finland, Ireland, South Korea, France, New Zealand, Turkey, and so on.

### *2.1. Definition of Foresight*

What does 'foresight' really mean? There are several definitions of foresight. According to Mike McMaster (1995), it is "the ability to see the shadow of the future being cast based on the expectation of continuous integration" (1995). Future is, by its nature, connected with the past when it happens. Therefore, depending on action or non-action at present, many futures are possible to occur, but only one of them will happen (Martin, 1995). In other words, foresight takes into account that there is not a single future.

Slaughter (1995) considers foresight as:

> Foresight is not the ability to predict the future…It is a human attribute that allows us to weigh up pros and cons, to evaluate different courses of action and to invest possible futures on every level with enough reality and meaning to use them as decision making aids…The simplest possible definition [of foresight] is: opening to the future with every means at our disposal, developing views of future options, and then choosing between them.

According to Slaughter (1995), foresight is a process that attempts to broaden the boundaries of perception in four ways; by assessing the implications of present actions, decisions, etc. (consequent assessment); by detecting and avoiding problems before they occur (early warning and guidance); by considering the present implications of possible future events (pro-active strategy formulation); by envisioning aspects of desired futures.

Irvine and Martin (1984), used the term foresight in the sense of outlook. This is not the same as a prediction, which would be closer to forecast. Foresight is:

> …[The] process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits (Martin, 1995).

Horton (1999) describes three consecutive phases of foresight as "(1) Collection, collation and summarization of available information and results in the production of foresight knowledge, (2) Translation and interpretation of this knowledge to produce an understanding of its implications for the future from the specific point of view of a

particular organization, (3) Assimilation and evaluation of this understanding to produce a commitment to action in a particular organization."

According to Webster (1999), foresight involves four processes: "(1) Deriving a list of 'critical' or 'generic' technologies which can emphasize different areas of innovation; (2) A consensus-driven discussion exercise that tries to classify possible developments in science and technology which are aimed to meet societal needs over the next 30 years; (3) A priority-classification process for the science and engineering base; (4) the identification and encouragement of fields of 'technological fusion'."

STRATA-ETAN Expert Group of the European Union DG Research defines ''foresight'' as:

> An important tool in the development and management of future oriented innovation systems, based within a wider context of future-oriented coordination activities in a society. It could be defined as a purposefully organised process bringing together expectations of diverse actors about possible development paths to formulate strategic views about the future that take into account broad social and economic developments.

In addition to that, the EU-supported FOREN programme defines foresight in A Practical Guide to Regional Foresight (2001) document as:

> a systematic, participatory, future-intelligence gathering and medium-long-term vision-building process aimed at present day decisions and mobilising joint actions. Foresight arises from a convergence of trends underlying recent developments in the fields of policy analysis, strategic planning and future studies. It brings together key agents of change and various sources of knowledge in order to develop strategic vision and anticipatory intelligence.

The same document classifies five essential elements of Foresight as "(1) structured anticipation and projections that are about long-term social, economic and technological developments and needs, (2) Interactive and participative methods of which exploratory debate, analysis and study, involving a wide variety of stakeholders, (3) Involving forging new social networks (4) Guiding strategic vision, to which there can be a shared sense of commitment, (5) Shared vision, not a utopia, that has to be explicit recognition and explication of the implications for present day decisions and actions."

As a result, four important aspects of foresight arise depending upon the definitions stated above. Firstly, foresight is a process that brings together key participants from different stakeholders to share knowledge about what sort of world to create in coming decades. Second, it is a systematic process to look into the future. Third, foresight studies are concerned with the longer-term visions that are generally more than 20 years. Fourth, the focus of studies should be on discovery of emerging generic technologies, in other words, technologies that are still at a pre-competitive stage.

### *2.2. Methods of Foresight*

The future needs to be constructed by the interaction of science, technology, and society and cannot be predicted (but foresighted) due to the current turbulent environment in which continuous and dramatic changes are taking place. Therefore, in the following lines, most of the methods employed by a foresight programme have been discussed. Various methods were originally developed during the 60s and 70s. However, because of their limited nature, there have been many research studies to modify and improve them for the requirements of the following decades. It should be stressed that the essence of a foresight programme is not to develop an accurate forecast, but to focus on the improvement of the capabilities of the foresight users to anticipate and deal with changes. This means achievement of an improved understanding of the major issues that the knowledge society will have to deal with in the long term.

The arising question is whether all foresight methods have the same capability to solve the systemic failures and whether they have similar reinforcements on the strength of a System of Innovation. The Practical Guide to Regional Foresight produced by the European Commission's FOREN Project divides methods into three according to the purpose for which they are to be used: methods based on electing expert knowledge to develop long-term strategies (like Delphi, expert panels, brainstorming, mind-mapping, scenario analysis workshops, and SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis), quantitative methods using statistics and other data, (such as trend extrapolation, simulation modeling, cross impact analysis, or system dynamics), and methods that assist identification of the

key points of action to determine planning strategies (such as critical technologies, relevance trees, or morphological analysis) (De Mesa, Munoz, 2005).

The foresight methods that have been mainly used in foresight activity are:

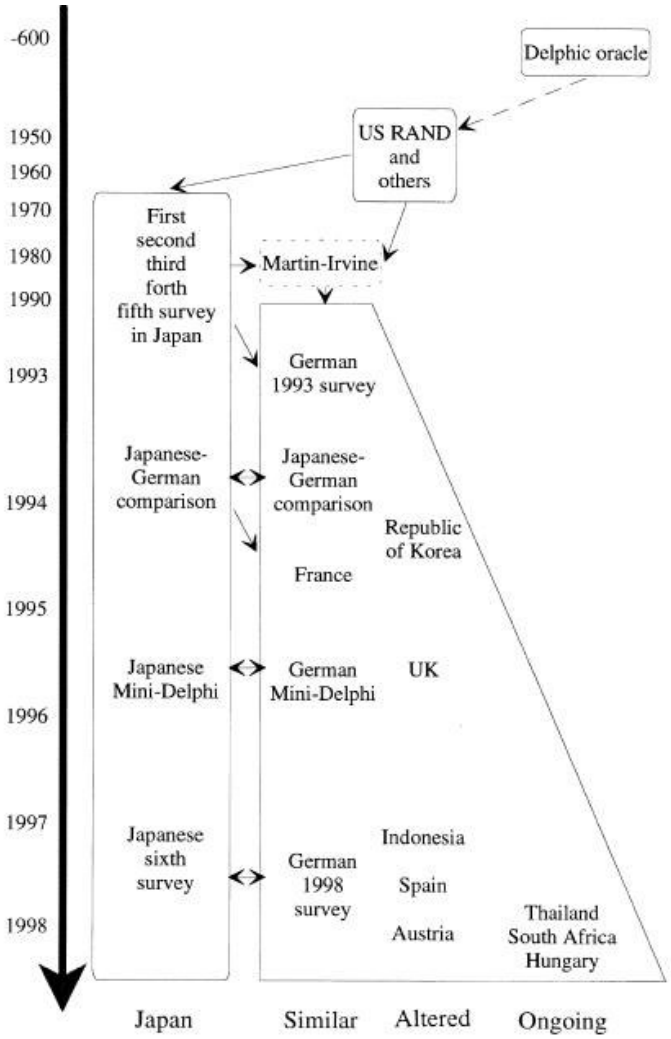
1. The Delphi Method
2. Expert Panel
3. Brainstorming
4. Mind-mapping
5. Scenarios Writing
6. SWOT
7. Trend Extrapolation
8. Simulation Modeling
9. Cross-Impact Simulation Models
10. System of Dynamics
11. Critical Key Technologies
12. Relevance Trees
13. Morphological Analysis

In the following pages, foresight methods that are mainly used in Vision2023, NBIC Study, and ManVis Study (their main goal is electing expert knowledge to develop long-term strategies) are examined. These methods work together to show the judgment of experts as systematic as possible.

### *2.2.1. The Delphi Method*

In The Practical Guide to Regional Foresight, it is stated that Delphi involves a survey of people believed to be experts in the areas being studied. In the most common form of Delphi, the opinions sought concern the particular developments that are likely to happen. Linstone and Turoff (1975, p. 3.) define Delphi as "a method for structuring a group communication problem". The Delphi method is considered useful especially for long-range aspects (20 to 30 years) (Grupp and Linstone, 1998).

The main initial Delphi work was performed at the RAND Corporation, Santa Monica, after 1948 (Figure 1). Forecasting, as it was known then, was motivated by Bush's book Science, The Endless Frontier, advocating the transformation of U.S. military economy research and development during World War II (e.g. the Manhattan Project) into long-term civil research and commercial exploitation. The earlier attempts were also spurred by the scientific successes of the Soviet planned economy (e.g. the hydrogen bomb and the launch of the Sputnik).




***Source: Grupp,H., Linstone H.A., (1998), National technology foresight activities around the globe-resurrection and new paradigms, Technol.Forecast.Soc. Change 60 ,p.90***

***Figure 1 Career of Delphi Methods***

Delphi is different from the other survey methods in that it asks participants, consisting of experts, to fill a questionnaire and asks them again to fill the same questionnaire but in this second round they are also supplied with the feedback about the results of their previous responses. Sharing the responses, without being unduly influenced by the people who have a manipulative attitude at meetings, or who are more prestigious, is the idea. Ideally, the owner of ideas different from a developing consensus would be required to explain their reasons for their views, and this would serve as useful intelligence for others. Often the goal (and the result) of a Delphi study is to achieve convergence of opinions. On the other hand, in some cases, the goal is not only to show convergence of opinions but also to identify dispute or non-convergence. (FOREN, 2001 )

The panel members will usually have widely varying estimates on each topic in the beginning of the process and do not always shift the opinion under the influence of the assessments given to them by the other panelists. Therefore, it is important to continue until there is stability, that is, until there is not much change between rounds (Linstone and Turoff, 1975).

Delphi forms a committee that seeks consensus. Delphi may, and does, exhibit bipolar views and does not force consensus. However, the number of rounds must be limited because of dropping interest – panel attrition- (Tübitak, 2001).

The main challenge for the Delphi is the generation of topics. As Linstone and Grupp (1998) state the origin of the statements is from elsewhere, like committees. Nevertheless, it is not necessary for Delphi to begin with issues generated elsewhere. In other words, it might begin with the issues uttered by the participants only.

As Murray (1979) states that Delphi method has three elements as; (1) partial or complete anonymity of the participants, (2) structured feedback to the participants, which is usually statistically summarized, and (3) iterative rounds.

It must be remembered that the Delphi method may not be considered as science due to the fact that the process, especially the number of iterative rounds, is closely related to the intuition of the survey board, and expectations tempered by any

contrary view will be mistaken (Tübitak, 2001). Moreover, Murray (1979) and Pill (1971) state Delphi as art not science. Murray (1979) criticizes Delphi method and gathers the arguments in the literature against Delphi method due to ambiguity of questions, selection of experts, changing panel membership, false consensus, accuracy, and he answers these arguments. Ambiguity of the questions is not unique to Delphi. Selection expert problem can be solved by asking the expertise level on the subject that is mention in question and taking the analyzing the result with weighting the answers with expertise level (Murray, 1979, p. 155). Changing panel members problem is not an important problem according to Murray (1979, p.155), because the process is an evolving nature as a result of iterative approach; therefore, maybe results will oscillate a little but at the end it will reach its stability. False consensus is not considered as a problem if the nature of Delphi study that also searches the differences is understood. Murray (1979, p. 156) states that the concept of accuracy does not apply because Delphi may also be used as structured technique to expose assumption, arguments on a particular subject to critical examination (p 156). Bias by the manager problem is not unique to this method, but the provided data is more convenient than the other methods (Murray, 1979, p. 158).

The main drawback of Delphi method time period it requires. Beyond the main drawback, it has some other drawbacks: (1) a narrow set of criteria for the field may lead to unrepresentative views or miss out important sources of knowledge (2) to find experts to answer a questionnaire at least twice is difficult and requires incentives; therefore, current studies are often limited to preparation and two rounds, (3) due to ignoring unique opinions that might be of special value as a result of pooling, it is difficult to find out reasons for extreme answers later on, as this anonymity has to be respected (FOREN, 2001 ).

### *2.2.2. Expert Panel*

Operation of the expert panels to present opinion on a certain subject is the most frequently used method in the foresight studies worldwide for electing expert knowledge to develop long-term strategies. As the discussion of conflicting viewpoints has a vital role in the foresight studies, representation of different viewpoints should be provided in panels. Based on the topics agreed in the foresight

subject to be discussed, each of the workshop group and sub-group conducts their studies in the science & technology and/or industrial & trade sectors. In some cases a consulting external expert in the particular field is required for. Main objective of the executive committee is to organize the workshop groups, to coordinate them, and to integrate the reports. In general, the expert panel method has its advantages in revealing the benefits of the foresight process (Tübitak,2001).

Problems of Expert Panels are stated as:

- The selection of panelists;
- Lack of motivation of experts;
- Over-dominance of strong personalities;
- Dangers associated with too narrow representation (FOREN, 2001).

An expert panel cannot produce a statistically significant outcome; moreover, it represents the synthesized opinions of the particular group (FOREN, 2001, p.105).

### *2.2.3. Brainstorming*

The main objective of brainstorming is to draw out ideas from a group of people (FOREN, 2001). As this process is self-explanatory and widely used, it does not need a complicated explanation. A period of freethinking is used to articulate ideas. In the initial phase, which is conducted under the pressure of restricted time, ideas are simply recorded word by word, without validity testing. In the second phase, the duplicate ideas are grouped, wild ideas are eliminated, and synergistic ones are combined as the idea evaluation process proceeds. At the end of the session, the group produces a set of ideas that have been tested in an ad hoc fashion and are approved for further and deeper evaluation for feasibility and relevance to the situation. In the early stages of formulating questions that need discussion or on which opinions need to be required, brainstorming can be a useful technique for expert committees and for a consultation management group (Tübitak, 2001)

Drawbacks of brainstorming are unworkable ideas, loss of discussion atmosphere, and stubborn opponents that refuse to consider each other's ideas (FOREN, 2001).

### *2.2.4. Mind-mapping*

Mind-mapping, a technique applied to brainstorming and other group discussion methods, allows for quickly charting group's ideas in logical groupings, even when ideas are given in a non-sequential manner that makes it a non-linear way of outlining information. Efficient brainstorming for ideas and creating a skeletal framework for later categorization of the information generated are the main advantages of this technique. (FOREN, 2001).

### *2.2.5. Scenarios Writing*

Scenarios are tools for synthesis, structuring thinking, and presentational purposes. The use of scenarios has become more popular because a scenario claims (a) to encompass the complexity of the real world and (b) enable alternative visions of the future to be presented in the form of a logical sequence of events. (Tübitak, 2001). Scenarios consist of visions of future states and courses of development, organized in a systematic way as texts, charts, etc. differentiate or lead to distinctive futures. After obtaining views as to critical choices and selection, the group is requested to consider what the strategic options might be for the specific scenario to be achieved. A commonly used method for eliciting relevant drivers as identifying Social, Technological, Economic, Environmental, Political, and Value-Based factors and issues (FOREN, 2001).

Drawbacks are difficulty in dealing with multiple images of plausible futures, lacking supporting analysis, and quantifying some scenarios (FOREN, 2001).

### *2.2.6. SWOT (Strengths, Weaknesses, Opportunities & Threats)*

SWOT analysis is an analytical tool, which should be used to categorize significant environmental factors both internal and external to an organization (e.g. country, institution) (FOREN, 2001). The basis of SWOT analysis lies in the in-depth analysis of an organization's strengths, weaknesses, opportunities, and threats within the context of a certain technological area or capability, in both their own and external viewpoints. The strengths and weaknesses are related to the inner dynamics of the organization. (Tübitak, 2001).

On the other hand, opportunities and threats are the situations external to the organization, which are able to improve performance when appropriately utilized and destroy the performance when required prevention measures are not taken (Tübitak, 2001).

Drawbacks of SWOT are inadequate definition of factors, lack of prioritization of factors, over-subjectivity in the generation of factors, and compiler bias (FOREN, 2001).

In summary, foresight opens up the possibility of negotiating a new and more fruitful relationship or "social contract" between science and technology, on the one hand, and society on the other (Martin, 1997). These process' benefits are encapsulated with 5Cs identified by Irvine and Martin (1984):

- Foresight has enhanced Communication (among companies and also among researchers within themselves, and among researchers, users, and founders)
- It has resulted in greater Concentration on the longer-term future
- It has provided a means of Coordination (again among researchers and between researchers, users, and founders)
- It has helped to create a level of Consensus on desirable futures over the next 10–20 years
- It has generated Commitment to turning the ideas emerging from the foresight programme into action.

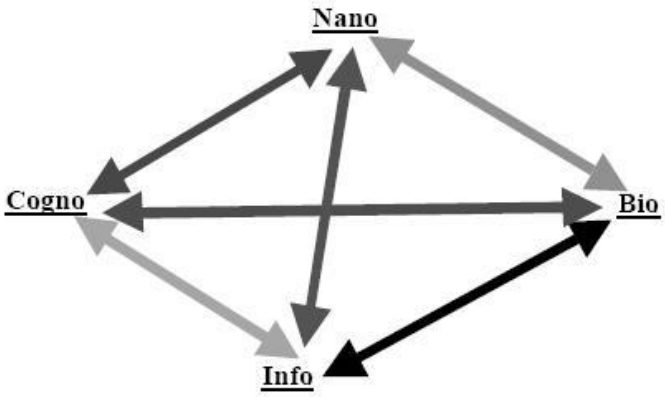
## *CHAPTER 3*

## *CONVERGING TECHNOLOGIES*

Half a millennium ago, artist-engineers like Leonardo da Vinci, Filippo Brunelleschi, and Benvenuto Cellini were masters of several fields simultaneously and are called as Renaissance man. The characteristic of the Renaissance man was their holistic quality, as there was a kind of integration among and an interdependence of all fields of art, engineering, science, and culture. In other words, the same exciting spirit and many of the same intellectual principles were relevant to all these fields. However, in $19^{th}$ and $20^{th}$ century, specialization has splintered the arts and engineering, and no one can master more than a tiny fragment. On the other hand, the threshold of a new renaissance in science and technology, based on a comprehensive understanding of the structure and behavior of matter, understanding of abilities of human body, especially brain, creating computing elements and networks appears (Rocco et al. 2002, p1).

### *3.1. What are the Elements of Converging Technologies?*

According to NBIC Report, " 'convergent technologies' refers to the synergistic combination of four major NBIC (nano-bio-info-cogno) provinces of science and technology, each of which is currently progressing at a rapid rate: (1) nanoscience and nanotechnology; (2) biotechnology and biomedicine, including genetic engineering; (3) information technology, including advanced computing and communications; and (4) cognitive science, including cognitive neuroscience" (Rocco et al. 2002, p.1).




***Sourece : Roco M.C, W.S. Sims Bainbridge (eds). , (2002), Converging Technologies for Improving Human Performance, Nano-, Bio-, Info-Technology and Cognitive Science. National Science Foundation. p.2***
***Figure 2 NBIC Tetrahedral***

Canadian National Research Council defines converging technologies in Bio-Systemics Synthesis Report as (1) Information technologies, (2) Biotechnology, (3) Nanotechnology, (4) Medical Science, (5) Cognitive Science, (6) Systems Science (Bouchard R., 2003, p8).

European Communities Report, Converging Technologies – Shaping the Future of European Societies, assigns converging technologies as (1) Nanotechnology, (2) Biotechnology (3) Information technology, (4) Cognitive science (Nordmann 2004).

Definitions of these technologies are required to understand the overall potential of the technologies and links between and among them.

### *3.1.1. Nanotechnology*

In nature, nanoscale does not have a narrow application field. Nature has built up complex systems that are composed of atoms and molecules. Rocks, the sea, and the air, everything is made of atoms and molecules and are complex systems like living organisms whose working is defined entirely at the nanoscale.

Nanoscience and Nanotechnology are both used in the research studies related to matter at a scale where its properties are defined and in the application of knowledge of material behaviour at the nanoscale.

One important objective of nanotechnology is to tie the new properties of tiny particles that show integrity of their nature, or that can be passed on to them by chemically "decorating" their surfaces with other molecules. This has various application fields such as new sensors that are able to detect and measure the pollution in the air or water rapidly, or analyze the blood. Another important objective is to design nanosurfaces that include production of new materials with modification of their physical and / or chemical structure at the surface. An example of this is the production of lightweight, odour-resistant, and stay-fresh packaging for food by integrating only a small percentage of nanoparticulate clay minerals in the surface of a polymer, resulting in enhanced impermeability and heat resistance.

It is possible that nanotechnology will enable the design and production of entirely new materials by understanding the properties of materials at the nanoscale. How the attributes of materials originate, and integration of these abilities in design of materials are some of the fields that nanotechnology is concerned with. The estimated number of possible materials to be produced by this technology is $10^{22}$. Therefore, it is not wrong to claim that nanotechnology can be one of the key components of arriving at almost an infinite potential in the production of materials.

Some specific topics of nanotechnology that are listed in Bio-Systemics Synthesis Report are (1) Nano-sensors, (2) Semiconductors, (3) Materials, (4) Micro-electro-mechanical systems, (5) Lab-on-a-chip, (6) Nanomedecine (Bouchard R., 2003).

### *3.1.2. Biotechnology*

Watson and Crick discovered the structure of DNA and explained that genes contain the information required to produce proteins. However, the potential of this discovery in medicine and other fields of human activity could not be utilized until the discovery of recombinant DNA and monoclonal antibodies in the early 1970s (McKelvey, 1997; Goujon, 2001; Eliasson, 2000). Industrial applications that are

expected to produce economic returns within relatively short time periods began after these two discoveries. Following developments in the 1980s are dependent heavily on technical progress, for example polymerase chain reaction (PCR), which allowed to magnify the quantities of DNA and of genetic material that could be available to researchers, and the rise of bioinformatics (Saviotti et al, 2000), a new discipline at the interface between biology and IT, which allowed the automation of the sequencing of DNA and greatly accelerated the Human Genome Project that gives opportunity to an extensive scope of new applications. Particular diseases that become the object of focused attention and emerging technical developments turned into the recognized subsets of biotechnology. Moreover, in the past the role of science is described as to improve the environment of human beings, but to leave human beings unchanged, modern biotechnology for the first time, allows mankind, to be able to radically modify itself (Salviotti, et al., 2005, p. 19).

Biotechnology is not an industrial sector, but it is a technology which is based on several scientific disciplines and which can affect a number of industrial sectors. The major sectors that can be affected are the pharmaceutical, agrochemical, food, and chemical sectors. Another field of concern of biotechnology is the environmental issues. As expected, the adoption of biotechnology in these sectors has not been uniform. The pharmaceutical sector was and still remains dominant. Other sectors, such as agriculture and food, were considered very promising, but the developments there have been far slower than expected. General industrial applications developed at a slower pace but are gaining momentum. In summary, biotechnology is a component of a system which comprises scientific institutions, industrial firms, financial institutions, and governing bodies.

Some of the specific topics that are related to biotechnology are (1) Biosensors, (2) Pharmacogenomics and personalized medicine, (3) Proteomics, (4) Predictive medicine, (5) Gene therapy, (6) Monoclonal vaccines, (7) Genetically modified organisms, (8) Stem cells, (9) Cloning, (10) Agriculture and food genomics, (11) Genetically modified organisms, (12) Animal genomics, (13) Aquaculture, (14) Environmental technology, including bioremediation, (15) Industrial biotechnology, (16) Biomaterials, and (17) Fuel sources (Bouchard R., 2003).

### *3.1.3. Information Technologies*

According to Wikipedia (http://en.wikipedia.org/wiki/Information_technologies), information technology is a broad subject concerned with technology and other aspects of managing and processing information. A narrowed definition is that information technology deals with the use of electronic computers and computer software to convert, store, protect, process, transmit, and retrieve information.

Computes are defined by Edward (1996, p.27) as "tools or machines, technical levers usefully interposed between practical problems and their solutions. But two essential features distinguish computers from all other machines (a) their ability to store and execute programs that carry out conditional branching and (b) their ability to manipulate any kind of symbolic information at all". Alan Turing (1950), devised a test to identify what artificial intelligence is. He claimed that if human beings are not able to identify whether an answer comes from a computer or another human being, then we can talk about the existence of artificial intelligence of the computer answering the question. This artificial intelligence debate still goes on as to whether Deep Blue can be called intelligent. In addition to artificial intelligence, there are fields such as virtual reality, network, human computer interaction, and so on. Information technologies are the widest area of all converging technologies. For example, "from [the] basic principle of base pair complementarity, DNA contains two elements crucial to any computer: a processing unit (the enzymes that denature, replicate and anneal DNA), and a storage unit (the regulatory 'instructions' encoded in DNA strings). Not only does DNA form a highly efficient storage system (as estimated one bit per cubic nanometer), but in the living cell, instructions are carried out in a massively parallel fashion (in contrast to the sequential processing of instructions in many computers)" (Thacker, E. 2004 p. 94).

The speed of acceleration in hardware sector of IT is incredible. From 1990 to 2001 speed of central processing unit (CPU) increased 393 times. A recently announced "Cell processor" developed by IBM, Sony, and Toshiba could move close to the Teraflops (ie. Trillion operations per second). In the same period, disc capacity has increased 1200 times, available random access memory (RAM) 128 times, wireless transfer speed 18 times battery energy density 2.7 times (Aarts and Marzano, 2003).

On the other hand, there are significant problems in software industry such as; (Bibel, 2005)

- Low rate of daily code production (even the best teams produce fewer than 10 lines of code/day)
- Existence of errors in codes (6 errors for per thousand lines of code)
- Low rate of completion in large projects (one of every three large projects scrapped before ever being completed)
- Low rate of success of finished projects ( 1 in 8 finished software projects considered "successful")
- Gigantic losses due to erroneous code (like the destruction of the Ariane-5 prototype and the Climate Orbiter which missed the Mars)

There are two general visions that are considered as the most important ones. The first is the integration of intelligent systems within the natural, human, and also the technical sphere. AI, virtual reality, (multimodal) Human/Computer Interface (HCI), humanoid robotics, and, generally, the coupling and reconciliation of the real with the virtual are considered as top issues for R&D (Research and Development) in the coming years. The other vision is the transformation of software production into a scientific discipline, incorporating new computational paradigms and leading to a high degree of automation as well as to an increasing autonomy, robustness, and tolerance of systems (Bibel, 2005).

Trends in Information technologies are miniaturization, distribution of collaborating devices (ubiquitous computing), distribution of problem solving, complex level of autonomy, migration from analog to digital, variety of phenomena in computation (physical, chemical, biological), coupling of virtual and real, and approximation of real and virtual.

Some specific topics that are related to Information technology are (1) “spiritual machines”, (2) Semiconductors (3) Photonics, (4) Storage, (5) Batteries, (6) Displays, (7) Networks, (8) Wireless, (9) Integrated and embedded devices, (10)

Software engineering, (11) Artificial intelligence (expert systems, fuzzy controls, neural networks), and (12) Peer-to-peer (Bouchard R., 2003).

### *3.1.4. Cognitive Science*

The name Cognitive Science was mentioned roughly forty years ago; however, its development started sixty years ago. From 1945 to 1970, the major themes and research agendas appeared. From the early 1970s to the end of the 1990s, a process of quantitative development, accompanied by the formation of academic institutions such as graduate programs, institutes, departments, journals was observed. For the past few years, it has shifted its main concern to neuroscience (Andler D. 2005).

The scope of cognitive science is the mind, or rather, the functions and processes of the mind. The main related disciplines are psychology, neuroscience, linguistics, computer science, philosophy (Andler D. 2005). Cognitive Science shows its importance and impulse with its ability to include and integrate all seriously tenable scientific approaches to the mind. The main related field is psychology. Cognitive science considers psychology as covering not only the traditional topics of memory, problem-solving, categorization, and the like, but also emotions, social cognition, linguistic competence, perception, action, selfhood, consciousness, etc. The result is that knowledge acquired in cognitive science can be exploited and developed by a whole range of technological disciplines, ranging from computer science, to health science, human and social science, education, law and government, industrial processes, trade, etc.

Another important field is neuroscience because studies of the brain focus on the brain's higher functions in order to reach a scientific understanding of the brain as an integrated system supporting the entire array of the mental functions. There is tremendous growth of new methodologies in the neurosciences, such as functional neuroimaging.

Major topics in this field are (1) perception and action, (2) memory, attention, and consciousness, (3) core knowledge, (4) categorization, the lexicon, the ontology, (5)

learning, (6) language and representation, (7) choice, rationality, decision, and (8) culture and social cognition (Andler D. 2005).

### *3.1.5. Convergence of Technologies*

Discoveries or inventions in one area will lead to progress in others. In this section, in order to understand the effect of one technology on another, development table of technology in human generation is given, then two examples that convergence of technologies will improve the technology in that fields. After that, convergence of nanotechnology, biotechnology, information technologies and cognitive science are examined, and principles and characteristics of this convergence is shown.

Table 1 shows that the history of some very significant augmentations to human performance: Improving our ability to collectively improve ourselves

***Table 1 - History of augmentations to human performance***

| Generations | Several Key Advancements (human kind, tools and technology, communication) |
|---|---|
| -m | Cell, body and brain development |
| -100,000 | Old Stone Age (Paleolithic), Homo Erectus, speech |
| -10,000 | Homo Sapiens, making tools |
| - 500 | Mesolithic, creating art |
| - 400 | Neolithic, agricultural products, writing, libraries |
| - 40 | Universities |
| - 24 | Printing |
| - 16 | Renaissance in S&T, accurate clocks |
| - 10 | Industrial revolution |
| - 5 | Telephone |
| - 4 | Radio |
| - 3 | TV |
| - 2 | Computer |
| - 1 | Microbiology, Internet |
| 0 | Reaching at the building blocks of matter (nanoscience) Biotechnology products Global connection via Internet; GPS/sensors for navigation |
| ½ | Unifying science and converging technologies from the nanoscale Nanotechnology products Improving human performance advancements Global education and information infrastructure |
| 1 | Converging technology products for improving human physical and mental performance (new products and services, brain connectivity, sensory abilities, etc.) Societal and business reorganization |
| N | Evolution transcending human cell, body, and brain? |

***Sourece : Roco M.C, W.S. Sims Bainbridge (eds). , (2002), Converging Technologies for Improving Human Performance, Nano-, Bio-, Info-Technology and Cognitive Science. National Science Foundation. p.23***

As seen in the table improvement in technology has a logarithmic relation with generation of human. According to this table, in the first four lines, thousands of generations are passed to improve a significant technology. However, as the last three lines indicate, each generation will have more than one item in their time period. It can also be observed in the following examples.

The first example: with computer-assisted techniques as functional magnetic resonance imaging (fMRI), cognitive neuroscience has made a great achievement in unlocking the secrets of the human brain. However, current methods have already used magnetic field strength at the utmost value for human safety. The smallest structures that can be imaged with this technique are about a cubic millimeter in size, but if this volume is in the brain, it can contain tens of thousands of neurons that does not let scientists see many of the most important structures In order to increase the resolution, the question is whether innovative computer techniques should extract more information from fMRI data or a wholly different method that is based on a marriage of biology and nanotechnology should be adopted to study the structure and function of regions of the brain.

The second example is in the area of information science, where there is a constant improvement in the speed and cost-effectiveness of integrated circuits. However, current methods are approaching their physical limits that have reached a density of more than a billion transistors on Intel's most recent Itanium-4 chip leaving room of the size of 65nm for each transistor (Bibel, 2005). Nanotechnology offers realistic hope that it will be possible to continue the improvement in hardware for a decade or even two decades longer than current methods will permit (Nordman, 2004). Recently, IBM researchers and collaborators have controlled a vial of a billion-billion ($10^{18}$) molecules designed to possess seven nuclear spins. This seven qubit quantum computer correctly factored the number 15 via Shor's algorithm and had its input programmed by radio frequency pulses and output detected by a nuclear magnetic resonance instrument (Roco et al, 2002). One very promising innovation opportunity is biocomputing, a host of software methods that employs metaphors from such branches of biology as genetics. Another is cognitive science, which can help computer scientists to develop software inspired by growing understanding of

the neural architectures and algorithms actually employed by the human brain (Nordman, 2004, Roco et al, 2002).

In the case of nanotechnology, biotechnology, information technology, and cognitive science, it is easy to see how these technologies are in interrelation with each other:

As everything consists of molecules, nanotechnology affects other technologies by offering solutions for all hardware-level engineering problems. The production of desirably architectured materials that allow design at the micro- and macroscale has a gateway to understanding of properties at the nanoscale. Nanotechnology changes biotechnology by developing new imaging techniques, probes and sensors (Nordman 2004). It plays a role to the miniaturisation demands of information technology. Also, nano-chips and nano-sensors are set to enable advances in the bioinformatics (Nordman, 2004, Roco et al, 2002).

By identifying chemical-physical processes and algorithmic structures of living systems that are tracked to their material basis in cellular and genetic organization, biotechnology affects other technologies. Biotechnology has an effect on development of nanotechnology by providing mechanisms of cellular recognition and targeted transport. It has potential application fields on information technology by developing, such as, the foundations for DNA-based computing. The unification of the three - information technologies, biotechnology and nanotechnology- , bio-mimetics and the investigation of cellular motors can enable nano-info R&D in nano-robotics. (Nordman, 2004)

With the ability to represent ever more physical states as information and model processes with a variety of computational methods, information technologies affect other technologies. Information technology provides the essential ability, named as computing power, for the research process in all disciplines. Precision control of patterning and intervention of nanotechnology are critical capabilities that are provided by it. Supplying biotechnology with the modeling complex processes and solving difficult research problems with them has significant effect on it. Simulation and modeling software also can allow nano-bio R&D in environmental monitoring. (Nordman, 2004)

With the studies on understanding the structure of the brain and neural system, cognitive science affects other technologies. Supplying the neural structure with information technologies creates opportunities to develop complex chip systems. Understanding the brain allows scientists to create artificial intelligent systems that are capable of judgment in critical situation or that work in routine conditions.

Four areas that are directly related with converging technologies are stated in NBIC Report. Development of entirely new categories of materials, devices, and systems to be used in manufacturing, construction, transportation, medicine, emerging technologies, and scientific research is the first area. Nanotechnology has a leading role in defining the abilities of materials. Information technology plays a crucial role in both research and design of properties of complex molecular and microscale structures. Industries of the future will use engineered biological processes in manufacture. Metabolism of living cells may be applied to development of new inorganic materials (Roco et al, 2002).

The second area is the living cell, which is the most complex known form of matter with a system of components and processes operating at the nanoscale. In order to imitate cellular processes on chips, ways of integrating nanotechnology, biotechnology, and computer science to create "bio-nano processors" for programming are investigated by considering the recent developments in biotechnology and microelectronics and their intersection called gene-on-a-chip approach (Roco et al, 2002). Another group of research studies try to understand how genes are expressed in a living body as physical structures and chemical activities carried out within the cell by using the ongoing work on virtual reality and augmented reality computer technology allowing scientists to visualize the cell from inside, and to see exactly the system of manipulating individual protein molecules and cellular nanostructures (Nordman, 2004, Roco et al, 2002).

The third area is fundamental principles of advanced sensory, computational, and communications systems, especially the integration of diverse components into the ubiquitous and global network. Complex dynamic systems and specific methods of sensing organic and chemical agents in the environment give an approach and data to

develop such systems (Nordman 2004, Roco et al 2002). Cognitive science will provide insights into ways to understand how the brain processes the information that is produced by organic sensors. (Roco et al, 2002)

The fourth area is the structure, function, and occasional dysfunction of intelligent systems, most importantly, the human mind. Studying the dynamic behavior of the brain, from the receptors and other structures far smaller than a single neuron, up through individual neurons, functionally specific modules composed of many neurons, the major components of the brain, and then the entire brain as a complex, but unified system requires unification of biotechnology, nanotechnology, and computer simulations (Roco et al, 2002). It is a challenge in understanding the mature human brain as a product of genetics and development. Information technology will be necessary in processing data about it. Moreover, in experimenting with artificial intelligent systems, such as in neural networks, genetic algorithms, autonomous agents, logic-based learning programs, and sophisticated information storage and retrieval systems, it is critical (Nordman 2004, Roco et al 2002).

According to NBIC Report (Roco et al, 2002), convergence of technologies is based on four principles. (1) Material unity at the nanoscale and technology integration from that scale allow scientists to control natural processes in order to engineer new materials, biological products, and machines at nanoscale up to the scale of meters. Moreover, the same principle helps to understand and control the behavior of both complex microsystems, such as neurons and computer components, and macrosystems, such as human metabolism. (2) Creation of NBIC transforming tools (nano-, bio, info-, and cognitive-based technologies), including scientific instruments, analytical methodologies, and radically new materials systems at the interfaces between separate fields of science and technology leads to their unification. (3) Understanding of the natural world and cognition in terms of complex, hierarchical systems are available thanks to developments in systems approaches, mathematics, and computation in conjunction with work in NBIC areas. In order to obtain maximum synergy along with the main directions of progress, the complex systems approach bestows holistic awareness of opportunities for integration. (4) Improvement of human performance becomes possible for the first

time in the history of technical achievement. Enhancing human mental, physical, and social abilities is possible with NBIC convergence. Better understanding of the human body and development of tools for direct human-machine interaction have opened completely new opportunities.

Table 2 shows a simplified framework of classification of areas which will improve individual human performance.

***Table 2 - Main improvement areas relative to an individual***

| Relative position | Improvement area |
|---|---|
| External (outside the body), environmental | • New products: materials, devices and systems, agriculture and food<br>• New agents: societal changes, organizations, robots, chat-bots, animals<br>• New mediators: stationary tools and artifacts<br>• New places: real, virtual, mixed |
| External, collective | • Enhanced group interaction and creativity<br>• Unifying science education and learning |
| External, personal | • New mediators: mobile/wearable tools and artifacts |
| Internal (inside the body), temporary | • New ingestible medicines, food |
| Internal, permanent | • New organs: new sensors and effectors, implantables<br>• New skills: converging technologies, new uses of old sensors and effectors<br>• New genes: new genetics, cells |

***Sourece : Roco M.C, W.S. Sims Bainbridge (eds). , (2002), Converging Technologies for Improving Human Performance, Nano-, Bio-, Info-Technology and Cognitive Science. National Science Foundation. p.7***

The characteristics of these converging technologies are stated in Converging Technologies – Shaping the European Society Report as (Nordman, 2004):

1. Embeddedness: Converging technologies, constructing structure for the background of human action in work, leisure, health-care, mobility, and

communication with these trends towards miniaturisation in information technology, towards molecular engineering in nanotechnoloy, towards gene specific targeting in biotechnology such as smaller medical implants and devices, 'invisible' sensors, or pervasive and unobtrusive imaging and communications technologies, work better, and human kind loses** the awareness of dependence on them or even their presence. Moreover, rather than producing artifacts to import into the natural environment, converging technologies allow the production of an artificial environment.

2. Unlimited research: As nanotechnology enables to control molecular and information technology's increasing ability to transform everything into information, nothing can escape the reach of Converging Technologies such as the mind, social interactions, communication, and emotional states. Converging Technologies help to expand the engineering paradigm into areas that were thought to be immune to engineering. When "social engineering" and behaviorist technologies emerged, these were not considered to be materially designed engineering solutions that would physically interface with social and cognitive processes. However, with converging technologies, one can expect that for every problem, someone may propose a more or less creative, viable or desirable technological fix.
3. Engineering the mind and the body: Regarding the mind and body, there are two fundamentally different approaches: "engineering of" and "engineering for". "Engineering of mind" involves a dedication to hard-wired technology. This hard-wiring is applied at the level of molecular design, or bio-chemical regularity such as DNA-replication. Especially, when the engineering of mental capacities and cognitive processes are considered, engineering of mind goes beyond decreasing or enhancing neural activity. The second approach recommends the heuristic "engineering for the mind". Converging Technologies may develop causal pathway by creating new tools that change how information is accessed and processed as it is done by video games. Whether it is the hardware and the software approach, the mind will be an explicit or implicit design target of converging technologies. An analogy takes place between "engineering of the body" and "engineering for the

body". Whether through the pathway of hardwiring or changes in the systems of self-monitoring, diagnosis, and healthcare delivery, the body will be a target of converging technologies.

4. Specificity: An example will be given to explain this character. The targeted medicine that is designed with the knowledge of the individual's genome can affect a cure without side effects. More generally, very specific tasks can be available with the convergence of technologies and knowledge systems. At the same time, it is a unique possibility to unite very specific and local constellations of expertise in a variety of contributing disciplines in the pursuit of a common goal.

Wallace, a participant in an NBIC workshop, summarizes the convergence of the four NBIC areas as:

> If the Cognitive Scientists can think it
>
> the Nano people can build it
>
> the Bio people can implement it, and
>
> the IT people can monitor and control it (Roco et al 2002 p.13)

### *3.2. Converging Technologies in Turkey*

#### *3.2.1. Nanotechnology in Turkey*

The nanotechnology research is not a new subject for the well known state universities namely Middle East Technical University (METU) and Hacettepe University (HU) in Ankara and Bosphorus University (BU) in Istanbul. Moreover, private universities such as, Koç University (KU) in Istanbul which has a Micro-Nano Technologies Research Center and Bilkent University (BIU) in Ankara which has Nanotechnology Research Center have strong influence on nanotechnology research (www.nanotr.bilkent.edu.tr). They are devoted to research on theoretical and experimental nanoscience and nanotechnology with a strong emphasis on education and training. Apart from universities, there are high technology institutes such as Gebze Institute of Technology, MAM- Marmara Research Center which is the research center of The Scientific and Technological Research Council of Turkey

(TÜBITAK) and Izmir Institute of Technology, which are highly productive in the nanotechnology research area.

Moreover, industrial companies are making their own progress with the help of their own R&D facilities. "One of the most important studies which attracted public attention was the boron studies; Nanotechnology-NNT Company produces crystallites of boron and adds to the motor oil, this suspended boron nano particles coats the inner sidewalls of the motors of the automobiles, which improves friction resistance and extends the motor life. Another important product is produced by a dye company, DYO-Nano, a wall paint which is resistant to paling and getting dirty and has the property of self cleaning. As a result of the nanotechnological research on polymer and surface modification, Arçelik Company, which is a white goods and electronics company, has marketed two products; the first is an odor filtering hygienic refrigerator and the second is a full protection triangle multi hygienic refrigerator." (http://digital.sabanciuniv.edu/elitfulltext/3011800000123.pdf) Moreover, Yeşim Textile Company has produced nano-structured smart fabrics that are ironed easily, dried quickly, and getting dirty hard, and these fabrics have been exported to an American textile company GAP. (Hurriyet, 2005)

### *3.2.2. Biotechnology in Turkey*

According to OECD's Biotechnology Statistics-2006 Report, there is no significant data about biotechnology in Turkey. On the other hand, Turkish Industrialists' and Businessmen's Association announced that the number of biotechnology firms in Turkey increased to ninety in 2005. According to the report 20% of these 90 biotechnology firms are in the technoparks (http://www.tusiad.org/haberler/basin/duyuruno850.pdf). Moreover, there are graduate and undergraduate programs in Turkish Universities. Especially Ege University (EGU), METU, HU, Ankara University (AU) and BIU have a leading role.

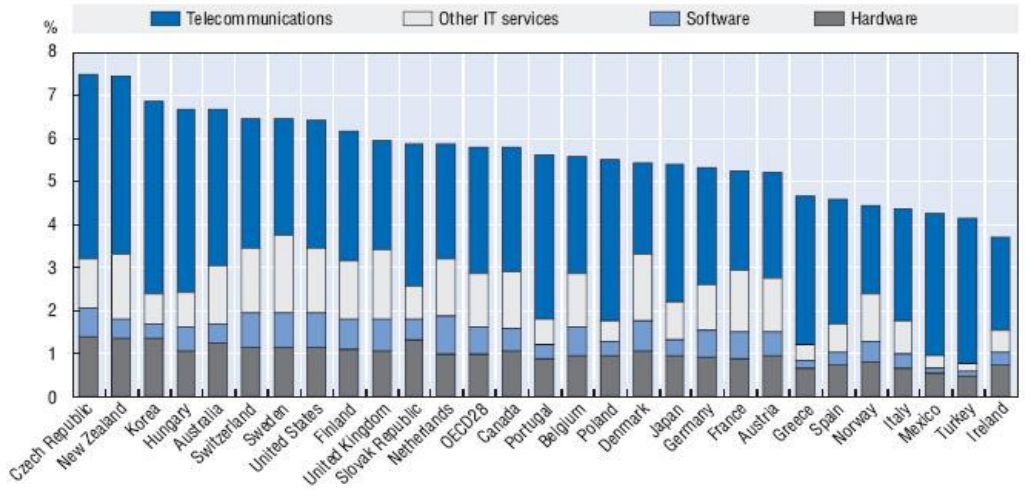
There are two governmental research centers. One of them is in MAM, Research Institute for Genetic Engineering and Biotechnology that carries out studies on embryonic stem cell technology, plant DNA markers and genetic mapping, tissue culture of plants peculiar to Turkey's flora, production of synthetic peptide and DNA

fragments (oligopeptides and oligonucleotides), screening, identification, and molecular characterization of alkaline producing bacteria from the local ecosystems of Turkey, random peptide libraries displayed on phage surfaces, and rapid screening techniques for the quantification of human gene mutations (http://www.rigeb.gov.tr/eng/java/aboutus1.htm). The second is Nuclear Biotechnology research center in Sarayköy, Ankara, which conducts studies mostly on domestic animals, and improvement of Radioimmunoassay (RIA) and Enzyme Immunoassay (EIA) techniques (http://www.taek.gov.tr/sanaem/html/nbb.html).

However, as Eva Dobos and Artemis Karaali (2003) state that the missing point of biotechnology in Turkey is the network among the actors.

### *3.2.3. Information Technologies in Turkey*

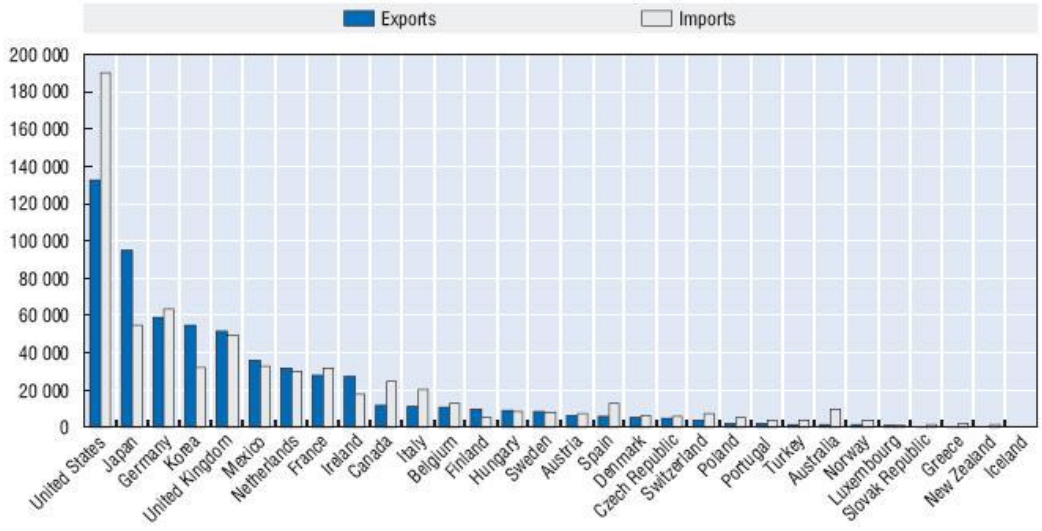
It is hard to define the situation of Turkey in Information technologies with research centers, or academic programs. Therefore, ratio of ICT (Information Communication Technologies) market in GNP (Gross National Product) is considered as informant. Turkey is in the second position from the bottom, the ratio between ICT market to GNP in 2003 as seen in figure 3.




***Source: OECD, (2004), OECD Information Technology Outlook, Paris, p45***
***Figure 3 ICT markets/GNP in OECD countries, 2003***

As seen in figure 3, dominant field in ICT market of Turkey is telecommunication; however, it is the result of the monopoly of Turk Telekom in 2003.

ICT good trade is another sign that determines the position of a country. As seen in figure 4, Turkey was among the last ten countries with poor ICT good trade in 2002.




***Source: OECD, (2004), OECD Information Technology Outlook, Paris, p48***
***Figure 4 OECD area ICT goods trade, (USD millions)***

Turkey has a higher import ratio in computer and related equipment, and in electronic components than its export ratio. On the other hand, audio and video equipment export ratio is significantly higher than import one, which results in the small amount of export as seen in figure 4 (OECD, 2004).

On the other hand, Turkey is 49$^{th}$ among 102 countries in terms of usage of ICT in business, which is determined by factors such as the level of business to business (B2B) and business to commerce (B2C): e-commerce, the use of ICTs for activities like marketing, and levels of on-line transactions (OECD,2004).

### *3.2.4. Cognitive Science in Turkey*

There is no cognitive science research center in Turkey. In all seventy one universities of Turkey, only METU and BU have graduate programs of cognitive science.

# *CHAPTER 4*

# *DATA ANALYSIS*

In this section, data of NBIC Report, ManVis Study, and Vision2023 study are analyzed. In the first part, concepts in vision statements of NBIC report are examined. In this part, nanotechnology, biotechnology, information technologies, and cognitive science are not analyzed separately. Visionary statements are separated depending upon to their concepts in NBIC report and same separation system is applied throughout the part.

In the second part, overall result of ManVis study is examined. Opinions of all participant experts about position of country, degree of expertise of countries, time of realization and importance vision statements, effects of statements in Delphi study are examined.

In the third part, Vision2023 study is examined. The first section covers converging technology related statements of the Delphi study; the second part contains panel reports, and the third one involves a synthesis report statements.

## *4.1. NBIC Report*

According to the foresight study, NBIC report of the USA, convergence of NBIC has significant impacts on such areas as work efficiency, the human body and mind throughout the life cycle, communication and education, mental health, aeronautics and space flight, food and farming, sustainable and intelligent environments, self-presentation and fashion, and transformation of civilization.

In other words, NBIC can be defined as the synergistic combination of nanoscience and nanotechnology, biotechnology and biomedicine, information technologies, cognitive science. NBIC not only covers these areas but it also covers some subtitles

such as genetic engineering that is included in biotechnology, advanced computing and communication that is included in information technologies, and cognitive neuroscience that is considered as part of cognitive science.

NBIC report searches for the answers of issues as: “What are the implications of unifying sciences and converging technologies? How will scientific knowledge and current technologies evolve and what emerging developments are envisioned? What should be done to achieve the best results over the next 10 to 20 years? What visionary ideas can guide research to accomplish broad benefits for humanity? What are the most pressing research and education issues? How can we develop a transforming national strategy to enhance individual capabilities and overall societal outcomes?” (Roco et al 2002 p.1)

The concern in this point is mainly related to visions not the strategies that make these visions to be realized. Therefore, in this section, visionary statements of this report will be summarized.

In the report, they are declared as: (Roco et al 2002 pp.5-6)

1. Fast, broadband interfaces directly between the human brain and machines
2. Comfortable, wearable sensors and computers
3. Robots and software agents
4. Ability to learn valuable new knowledge and skills more reliably and quickly
5. Ability to communicate and cooperate profitably across traditional barriers of culture, language, distance, and professional specialization.
6. Improvement in the human body as more durable, healthier, more energetic, easier to repair, and more resistant to many kinds of stress, biological threats, and aging processes.
7. Creation of materials that have exactly the desired properties, including the ability to adapt to changing situations, high energy efficiency, and environmental friendliness.
8. Compensation of many physical and mental disabilities and eradicatation of them.

9. Lightweight, information-rich war fighting systems, uninhabited combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence-gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks.
10. Worldwide instantaneous access to needed information, whether practical or scientific in nature.
11. Tremendously expanded creative abilities, both with a variety of new tools and through improved understanding of the fountain of human creativity.
12. Ability to control the genetics of humans, animals, and agricultural plants.
13. The vast promise of outer space.
14. Formulation of new organizational structures and management principles.
15. Improvement in awareness of the cognitive, social, and biological forces.
16. Improvement in human-machine capabilities as "intelligent environments".
17. Greatly increase in yields and reduce in spoilage ***
18. Safe, cheap, and fast transportation systems, extremely high-efficiency vehicle designs.
19. Revolution in science by importing approaches pioneered in other sciences.
20. Transformation of formal education by a unified but diverse curriculum.

Converging technologies have significant effect on six major areas. (1) Overall potential of converging technologies, (2) Expanding human cognition and communication, (3) Improving human health and physical capabilities, (4) Enhancing group and social outcome, (5) National security, (6) Unifying science and education are arbitrated as major areas.

1. Overall Potential of Converging Technologies: It was identified that their synergistic development is defined as an outstanding opportunity at the interface and frontier of sciences in the following decades. Science and engineering must offer new visions of what is possible to achieve through interdisciplinary research projects designed to promote technological convergence. (Roco et al 2002 p.14)
2. Expanding Human Cognition and Communication: Its needs and opportunities are examined in the areas of human cognitive and perceptual functions, communication between individuals and machines that are programmed with

human-like characteristics, and the ways that convergent technologies could enhance our understanding and effective use of human mental abilities. Five areas, (1) The Human Cognome Project, (2) Personal sensory device interfaces, (3) Enriched community through humanized technology, (4) Learning how to learn, and (5) Enhanced tools for creativity are defined in order to achieve technological convergence. (Roco et al 2002 p.14)

3. Improving Human Health and Physical Capabilities: Primary focus is on physical abilities of the individual. Six high priority technological capabilities are announced for the improvement of human health and physical performance: (1) Bio-nano machines for the development of treatments, including those resulting from bioinformatics, genomics and proteomics; (2) Nanotechnology-based implants as replacements for human organs or for monitoring physiological well-being; (3) Nanoscale robots and comparable unremarkable tools for medical intervention; (4) Extending connections in brain-to-brain and brain-to-machine interfaces to the human neural system; (5) Multi-modality platforms for vision- and hearing-impaired people; and (6) Virtual environments for training, design, and forms of work that are not limited by distance or the physical scale. (Roco et al 2002 p.14)
4. Enhancing Group and Societal Outcomes: The implications of technological convergence for human social behavior, social cognition, interpersonal relations, group processes, the use of language, learning in formal and informal settings, and the psycho physiological correlates of social behavior are examined. It is stated that NBIC technologies would remove barriers to communication caused by disabilities, language differences, geographic distance, and variations in knowledge, thus greatly enhancing the effectiveness of cooperation in schools, in corporations, in government agencies, and across the world. (Roco et al 2002 p.15)
5. National Security: Radically changing nature of encounters in this new century and the opportunities to strengthen national defense offered by technological convergence are examined. Seven highly diverse goals are spotted: (1) Data linkage and threat anticipation; (2) Uninhabited combat vehicles; (3) War fighter education and training; (4) Responses to chemical, biological, radiological, and

explosive threats; (5) War fighter systems; (6) Non-drug treatments to enhance human performance; and (7) Applications of brain-machine interfaces. (Roco et al 2002 p.15)

6. Unifying Science and Education: Opportunities for unifying science and the current limitations of scientific education are examined. Radical transformation in science education from elementary school through postgraduate training is stated as a need. Part of the answer will come from the convergence of NBIC technologies themselves, which will offer valuable new tools and modalities for education. Necessity of new curricula, new concepts to provide intellectual coherence, and new types of educational institutions are stated. (Roco et al 2002 p.16)

### *4.1.1. Expanding Human Cognition and Communication*

This section is about the potential to enhance individuals' mental and interaction abilities with the help of technological breakthroughs on NBIC. There are five visionary subtitles: (Roco et al 2002 pp.97-178)

1. The Human Cognome Project: It is a project that requires full co-operation of NBIC fields. Not only complete mapping of the connections in between the human brain and understanding, but also research on many fields of human endeavor, including education, mental health, and communications are the main concerns. Understanding of the human mind in absolute manner would allow designing technologies that are appropriate for human. In addition to these, there are some possible consequences of expanding human cognition like virtual presence with fooling sense, better sense with human made sensors like eyeballs, better memory with additional memory unit, or better imagination.
2. Personal Sensory Device Interfaces: Development of personal sensory device interfaces to enhance human abilities to perceive and communicate is another vision. Wearable technologies that enhance people's ability to sense their environment will increase and focus on at least two different areas:

a) Environmental sensing, which is human ability to sense aspects of environment (for example, the quality of the air we are breathing) that human normal senses cannot detect.
b) Social sensing, which is like the human's ability to be aware of people in immediate vicinity (personal information managers (PIMs) connected via wireless Personal Area Networks (PANs)). PIMs contain rich personal information, and PAN is the wireless network of flowing this information.

3. Enriched Community: NBIC sciences give a chance to humanize technology rather than to dehumanize society. Socio-tech will raise our ability to predict behaviors as the accumulation, manipulation, and integration of data from the life, social, and behavioral sciences, using tools (IT, Nano, Bio) and approaches (cognitive). It will allow us to block undesirable behaviors before causing significant harm to others and to support and encourage behaviors leading to greater social goods. In addition to that, as the software becomes as complex as biological systems, they will able to function more human like. Evolutionary learning and machine learning are the important areas that NBIC technologies converge.
4. Learning How to Learn: How and why people learn will be the goal that would revolutionize science, mathematics, and engineering education. Everyone will need to learn new skills and fundamental knowledge throughout life. It will not be as easy as a scene in the film Matrix; however, the knowledge of brain and neuron manipulating tools will be possible.
5. Enhanced Tools for Creativity: Biologically inspired techniques, such as evolutionary design methods analogous to genetic algorithms, small-scale design activities in the nano scale, and understanding the complex structure of the brain promise new developments in such areas as visual language, personalized design, designing around defects.

Moreover there are some crazy visions that are mentioned in the report such as downloading one's self into new hardware, instant learning, hive mind, speed-of-light travel, and self-directed evolution.

### *4.1.2. Improving Human Health and Physical Capabilities*

This section is related to strengthening the physical or biological capabilities of individuals. The main concern is to focus on health, diseases, and treatment of patients. There are six major technology fields: (Roco et al 2002 pp.179-274)

1. Nano-Bio Processor: This involves treatments with imitating human body by chips that are programmed modeling the biological structure and responses of body. The development of a "biological microprocessor" for synthesizing and analyzing biomolecules on nano platforms (liposomes, nanoparticles, selfassembled monolayers, and membranes) in fluids is the issue. There are three main functions of these "biomolecular nanotransducers"
    a. As multiplexed nanomedicines capable of long duration, in vivo targeted detection, diagnosis, and treatment of molecular diseases;
    b. As key ingredients of smart coatings for environmental monitoring of toxins/pathogens;
    c. As engineered biomolecular nanosystems that imitate cellular functions for fundamental biology experiments.
2. Self-Monitoring of Physiological Well-Being and Dysfunction Using Nano Implant Devices: Biosensors, products of nano technology, enable real time monitoring biological activity, and patients can learn how to control various body functions. Improvement in biofeedback mechanism will enable human beings to willfully stimulate inside their own bodies with small and highly specific biological changes resulting in large health- and performance-enhancement. Moreover, screening body and standard routines of it with nano materials enable early diagnosis of diseases. Noninvasive treatments with nano-medicine and remote control of nano scale materials to defend the body and destroy unwanted materials will be available. In addition to that, treatment or slowing down the process of diseases as a result of molecular deformation and cellular function decay such as Alzheimer will be possible by touching the molecules and cellular bodies with nano-materials.
3. Nano-Medical Research and Intervention Monitoring and Robotics: Cognitive activities of the brain and process in the body are the fields of

interest with the help of nano-enabled unremarkable tools. Another is that reducing the invasive effect of the surgery scalpel with nano-robots. Moreover, reducing the risk of post-surgery zone by monitoring patient with nano scale screening tools is another vision.

4. Multimodalities for Visual- and Hearing-Impaired: The potential to change computer interface architecture such as holographic outputs, force-feedback, vibrotactile, vastly improved natural speech interfaces, and real-time close captioning are the improvements in NBIC technologies for disabled people. Multimodal input and output interfaces will be the key point of human-computer (HC) interaction. NBIC will lead to improving assistive mobile teleportation device for disabled people. A person sitting in it can able to move in any direction, horizontal or vertical, free from obstacles such as stairs. Functional artificial limbs, which might even be better than existing human limbs and artificial devices for hearing, vision, and cognitive abilities such as comprehension and memory, are the concerns of NBIC.
5. Brain-to-Brain and Brain-to-Machine Interfaces: There are two visionary projects in this section:
    a. Neurovascular approach: With the analogy of cardiovascular structure of the body and the use of this system in the treatment, neurovascular structure considered as a hardware/software approach that allows a direct brain interface and the classification of its functional states will be used as a kind of invasive approach.
    b. Establishing direct links between neuronal tissue and machines that would allow direct control of mechanical, electronic, and even virtual objects as if they were extensions of human bodies is another visionary project. It enables the voluntary neural activity to control machines, electronics, or even virtual objects.
6. Virtual Environments: Marriage of nanotechnology to information technology can create realistic virtual environments and geographies. Biotechnology, guided by cognitive science, will give opportunities to humans to experience new environments beyond the limits of human senses. It is possible to fool human senses as s/he is at remote locations or at

imaginary environment. Design and social acceptability of such a large project will be achieved with these simulation systems.

In addition to these titles, there are some visions that can not be stated in any of the previous sections such as improvement in the functionality and design of houses or public spaces, allowing voice command, or intelligent applications. In addition to that, NBIC has the potential to improve communication on a global scale (e.g., universal translation devices), which would allow to a greater exchange of knowledge among people.

### *4.1.3. Enhancing Group and Societal Outcomes*

This section is related to social effects of NBIC and social effects on NBIC. As this study focus on visions related to social effects of NBIC rather than social effects on NBIC, the latter is not covered. There is only one major technology field: (Roco et al 2002 pp.275-326)

1. The communicator: There are three application areas of this NBIC tool:
    a. The Individual Information Component: Bioauthentication component will save time in initial socialization process by identifying humans in society. It will work as a translator in a group. It will determine what stress levels, information density, and learning rates work best for the individuals; moreover, it will provide support to the individual in learning the topic by changing the mode of learning to the best for that individual.
    b. The Avatar Component: It is the component that represents the human in reality and in cyberspace as an autonomous computer agent, used in dangerous situations, resident nurse, perceives what personal avatar encounters, training avatar.
    c. The Environmental Interface Component: As the environment senses present individuals, and process their specifications, each individual receives fitting information for him/her. Learning and teaching strategies differ from individual to individual. In addition to that participation in a meeting or conference virtually will be supported by

this component. Moreover the messages in these meetings are structured as the best understanding model for individuals.

There are some big brother visions such as social engineering and social software that act as a part of a legal and police structure.

### *4.1.4. National Security*

There are seven goals in this section that can be achieved by the help of the NBIC technologies. (Roco et al 2002 pp.327-362)

1. Data linkage, threat anticipation, and readiness: With the help of information technologies, it is possible to acquire a large volume of data regarding potential enemy organizations and to operate high speed data linkage among many databases that can be handled and analyzed with the help of nano technology. Understanding how the opponents analyze and make decisions will be possible with modeling the cognition processes of enemy.
2. Uninhabited combat vehicles: Automation technology will enable us to replace vehicles driven by human with the ones driven by machines. There are no pilots, captains, or tank drivers inside the vehicle in many dangerous warfighting missions. The current trend of nanotechnology, miniaturization, will reduce the weight, size, and power of the on-board systems in the air vehicle and will increase information processing power. Understanding of how pilots process the massive amount of information coming from environment will allow to designing an artificial “brain” to process the information and to control the vehicle autonomously. The uninhabited vehicle with an artificial brain can emulate a skillful fighter pilot (or more as needing no oxygen, being unsusceptible to g-force) in its missions, except for the circumstances requiring strategic or firing decisions. As the brain, it will store and retrieve of massive amounts of data and fuse information, allowing the system to make more precise decisions via target recognition and situation awareness.
3. Warfighter education and training: Storage and transfer of information about human and environment will be available with light and adaptive materials as

a suit. Moreover, retinal projection view and internal memory unit embedded to human will handle information. Computers with voice manipulation, language translators, tracking unit integrated weapons will be the common tools of a warfighter. One can envision a virtual-reality teaching environment that is tailored to the individual's learning modes, utilizes contexts stimulating that individual, and reduces any embarrassment over mistakes. The information exchange with the computer can be fully interactive, involving speech, vision, and motion. Nano devices will be essential to store the variety of necessary information and to process that information in the millisecond time frames necessary for real time interaction.

4. Chemical/biological/radiological/explosive (CBRE) detection and protection: Microfabricated sensor suites will provide ample, affordable, error-free forewarning of chemical, biological, radiological, or explosive threat. For those who must work in a contaminated environment, individual protection (masks and clothing) will induce heat stresses no greater than conventional uniforms while providing full protection. Decontamination and neutralization procedures will be effective against agents, yet will be relatively kind to people and the environment. Monitors will provide information on warfighter physiological status and initiate any necessary prophylaxis.
5. Warfighter systems: Marriage of nano-technology and information technologies will enable a warfighter to have a larger memory capacity, to process more speedily and to have a data transfer rate of the mobile light weight devices. The input device in these mobile devices will be vocal and the output platform will be paper-thin or directly placed on the retina. Sensors that are not detected easily, and inhabitant vehicles provide a warfighter definite data about the situation. Target tracing mechanisms on highly accurate firing weapons will be available to the warfighter. Moreover sensors on the armor will enable to monitor the warfighter body.
6. Non-drug treatments for enhancement of human performance: Interaction of NBIC technologies enables counterbalancing sleep deprivation and diminished alertness, improving physical and psychological performance, and increasing survivability rates from physical injury. Developing and

understanding how to use nano particles that are interacting only at specified sites as treatments is the role of nano technology, developing a detailed inventory of the effects of electromagnetic on cells and neuronal network is the role of biotechnology, developing methods to shape optimal electromagnetic pulses to heal the cells or neurons is the part of information technologies, and finally understanding how electromagnetic can be used to manipulate cognitive performance is the role of cognitive science.

7. Applications of brain-machine interface: Transmitting and receiving brain signals requires nano-technology depended devices. Understanding neural structure and measuring the brain electromagnetic activity depends on improvements in biotechnology, and the nature of the subject is directly related to cognitive science.

### *4.1.5. Unifying Science and Education*

Liberal arts, engineering and science are converging. The first evidence of this is convergence of nano-bio-info-cogs. This basic concept of merging science will affect the teaching process from beginning K-12, to undergraduate and graduate education. Moreover, there will be another affect of NBIC on education, changing the tools and style of education with use of new devices. (Roco et al 2002 pp.363-405)

There will also be a change in the curriculum of the K12, which will have to cover the newly technologies and developments through converging technologies such as in Biology. Contents of the courses have to be interdisciplinary. (Roco et al 2002 pp.363-405)

Teaching will be changed in order to improve the learning capacity of the child. Cognitive tools such as neurological-based technologies, and cognitive function measurement technologies will be used in tandem with computer based attention and memory enrichment approach. Other improvements in attention and stress management will take place via using brainwave and autonomic nervous system (ANS) biofeedback technologies. Widespread computer software will enhance academic cognitive abilities delivering brainwave biofeedback or neurofeedback for

attention deficit disorder. Physiological feedback will be common in daily activities (Roco et al 2002 pp.363-405).

Tools of education will be modified as a true 24/7 educational resource. High-fidelity simulations will be available in telepresence and intelligent agents. Virtual reality technologies will provide a tool set such as digital game-based learning (DGBL) with meaningful game context, effective interactive learning processes including feedback from failure, and the seamless integration of context and learning. Moreover, monitoring the brain activities of students during their engagement in educational material will provide data that will help to improve the education materials according to the needs (Roco et al 2002 pp.363-405).

### *4.2. ManVis Study*

ManVis is manufacture vision of Pan-European study. Turkey is one of the twenty two participant countries. Main aim of the study is to accompany the ongoing policy process of enhancing European competitiveness in manufacturing industries and to include views of European manufacturing experts (Arialla et al., 2005 p1.). It involves six reports. In this section "Manvis Report No. 6 - Manufacturing Visions Policy Summary and Recommendations", "ManVis Report No. 3 - Manufacturing Visions – Integrating Diverse Perspectives into Pan-European Foresight (ManVis) Delphi Interpretation Report" and "ManVis Report No. 2 - Preliminary Results from the 1st Round of the ManVis Delphi Survey" are examined.

Two step Delphi study is the main data source of the vision study and Report No 2 and Report No 3 cover the results of Delphi study. 3112 experts participated in the first survey round; whereas, in the second round 1359 experts participated (Dreher et al, 2005, p.4). This data set, ManVis Delphi study, is used to find out the lagging, time of realization, effects and importance of the selected statements.

There are several statements that are related to three of the converging technologies. In the ManVis Study, it is stated that advanced materials microsystem technologies, information and communication technologies, nano- and biotechnologies allowing for a bottom-up approach are four main groups of technologies that are affecting

technologies of manufacture in the last two decades. Nano technology is considered in micro-electromechanical devices, smart materials, products using nanocoatings and bottom-up manufacturing technologies; biotechnology is considered in bottom-up manufacturing technologies; and Information technologies are considered in micro-electromechanical systems, and long-term automation visions such as human-machine interfaces that are capable of man-machine speech recognition, self-learning systems and co-bots (Dreher, 2005).

First Round Delphi Questionnaire of ManVis is divided into two. First section is about general concept of the manufacturing. It covers "Manufacturing Technology", "Strategy, Organization and Management", "Product Features and Concepts", and "Logistics/Supply Chain" (Arialla et al., 2005). "Manufacturing Technologies" and "Product Features and Concepts" involve nano technology, biotechnology and information technology related statements. Second section is related with sectors. There are six major sectors (Arialla et al., 2005):

1. Machinery
2. Fabricated Metal Product
3. Electronic, Electrical Equipment and Instrument
4. Rubber and Plastic
5. Traditional Product
6. Transport

All of these sectors, except for Traditional Products sector, have Delphi statements that are related with nano technology; Machinery and Electronic, Electrical Equipment and Instrument sectors have statements that are related with information technologies, and Machinery sector has statements that are related with biotechnology.

In general concept, there are three statements that are related with nano technology as nano manufacturing (S003), smart materials (S028), and nano material coating (S030). In sectors concept, three statements are related with nano technology: Adaptronic materials (S066) statement in machinery sector, nanotechnology (S072)

in fabricated metal product sector, metrology for micro and nano scale (S092) in electronic, electrical equipment and instrument sector.

Biotechnology is considered in general concept with one statement that is manufacturing with living organisms (S004). There are two statements in sectors section, and both of them are in electronic, electrical equipment and instrument: Organic semiconductor (S091) and MEM in health and medicine (S093).

There are eight statements in general concept about IT. These are intelligent control (S001), human machine interface (S002), MEMs (S005), cobolts (S006), flexible automation (S007), customization (S014), electronic labels (S034), customization by software (S035). High automation (S045), automatic CNC (Computer Numerically Controlled) programming (S064), virtual machine simulation (S065), NC software (S068), wireless communication (S069), customization ICT tools for end users (S079), virtual reality tools (S080), wireless electronic recharging (S088), non-optical semi-conductors (S090), organic semi-conductors (S091), MEMS (Micro Electrical Machine System) in Health and Medicine (S093), High Speed Optical Communication (S094) are the statements of sector sections.

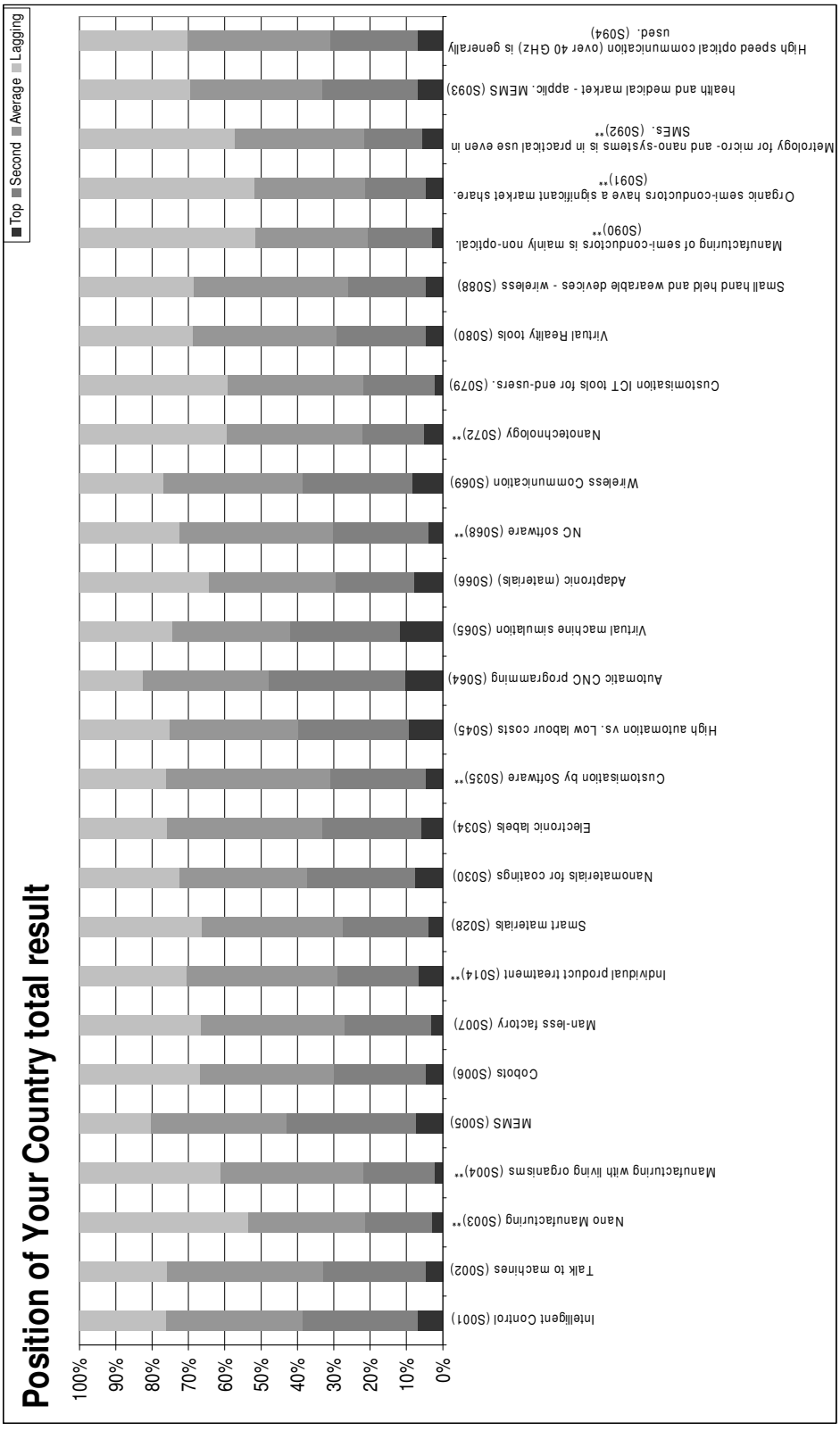



Figure 5 Position of EU according to all participants

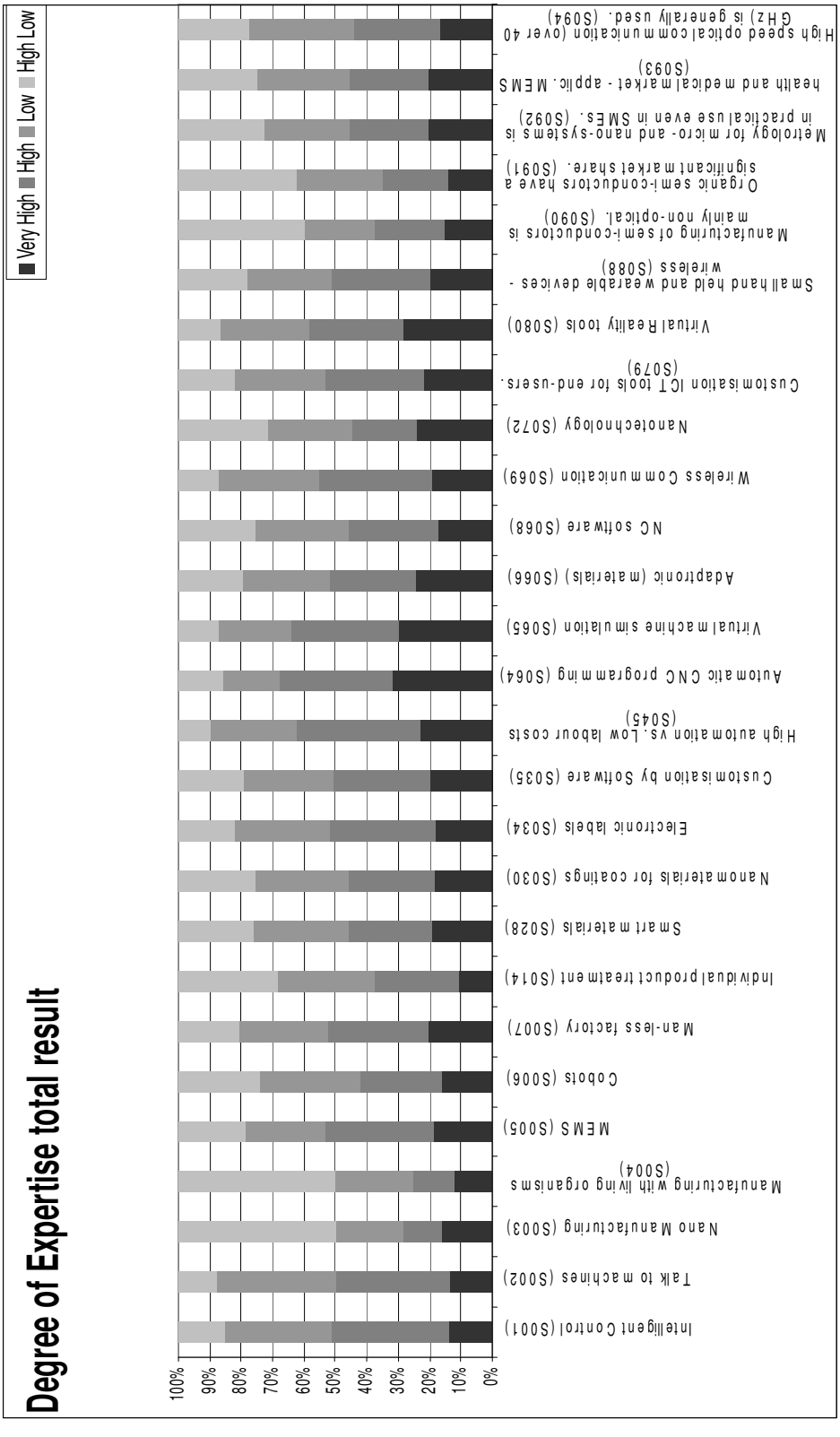



Figure 6 Degree of Expertise in EU according to all participants

### *4.2.1. Nanotechnology*

Nanotechnology related statements are nano manufacturing (S003), smart materials (S028), nano material coating (S030), Adaptronic materials (S066), nanotechnology (S072), metrology for micro and nano scale (S092).

In nanotechnology, as seen in Figure 7, except the "nanotechnology for coating" statement, 90% of the experts state that time of realization of those statements are after 2010. More than 50% of the experts considered that "nano manufacturing" and "nanotechnology" statements have realization time after 2020. Moreover, importance of "nanotechnology of coating" has more than all of the nanotechnology related statements. However, "never" and "Don't know" answers in "nano manufacturing" statement is 40% of the experts and it is 29% in "adaptonic" and "nanotechnology" statements.

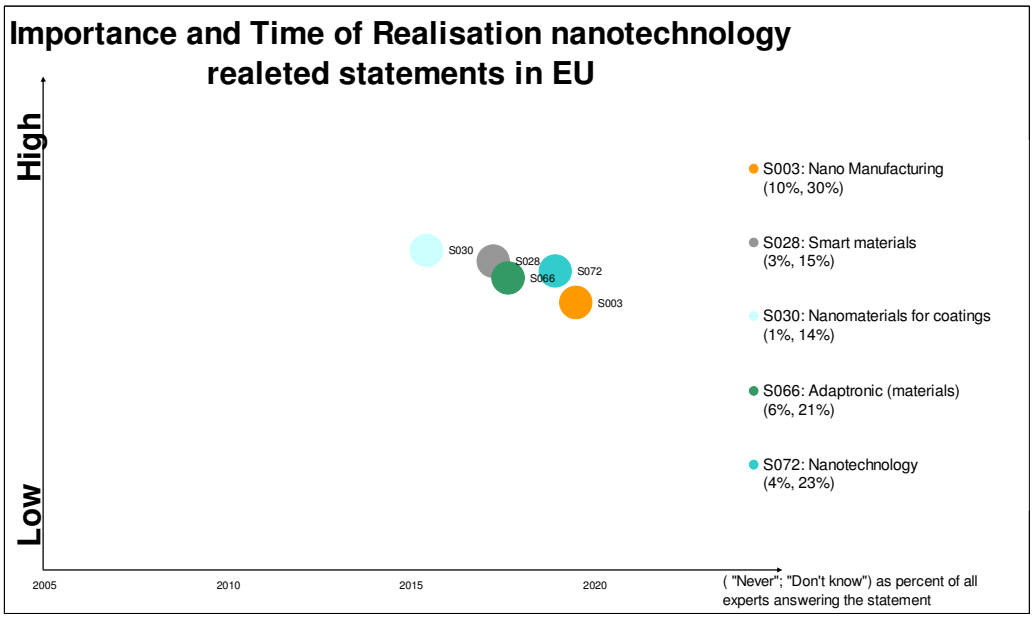



***Figure 5 Importance and time of realization nanotechnology related statement of ManVis in EU***

On the other hand, degree of expertise on nanotechnology statements in EU is considered "high" by approximately %50 of the experts, expect for "nano manufacturing" statement. This statement is considered "very low" by 50% of experts.

In terms of "nanomaterial coating" statement, 40% of the experts rank EU as either "top" or "second" as seen in Figure 6. However, the rest of the nanotechnology related statements are considered as "lagging" or "average" by about 70% of the experts as seen in Figure 5.

Moreover, all of the nanotechnology related statements are considered to have positive effect on living and working conditions. Minimum 45% of the experts claimed that they will increase the living and working conditions. Moreover, competitiveness and environmental quality are expected to improve. However, "regional differences" will increase, too. Moreover, "nano manufacturing" will decrease the employment as seen in Figure 8.

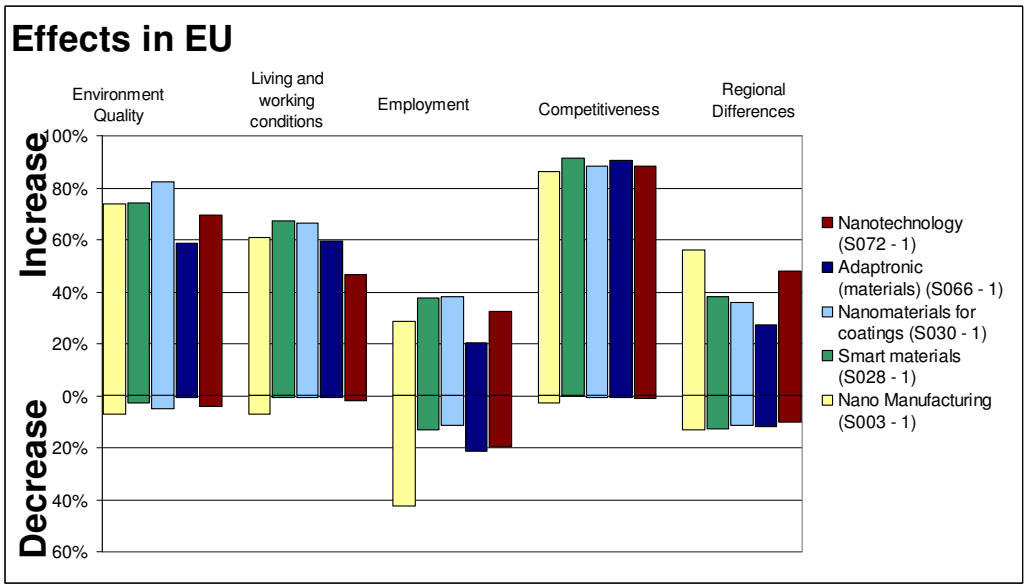



***Figure 6 Effects of nanotechnology related statement of ManVis on EU***

### *4.2.2. Biotechnology*

Biotechnology is considered in general concept with one statement that is manufacturing with living organisms (S004). There are two statements in sectors section: Organic semiconductor (S091) and MEM in health and medicine (S093), and both of them are in electronic, electrical equipment and instrument.

In biotechnology related statement, 90% of the experts state that time of realization of those statements are after 2010. All of the statements are considered as time of

realization between 2015 and 2020 as seen in Figure 9. Moreover, there is no significant relative importance between them. However percentage in sum of "never" and "Don't know" answers in "manufacturing with living organisms" and "organic semi conductor have significant market share" statements are 31% and 28% respectively .

Moreover, the degree of expertise on "Health and medical market application of MEMS" is considered "high" by about %50 of the experts as seen in Figure 6. However, the rests of the statements are considered as "low" or "very low" by 70% of the experts.

"Health and medical market application of MEMS" statement as far as EU is concerned is viewed as "average" or "lagging" by 65% of expert opinion. Moreover, the rest of the biotechnology related statements are regarded as "average" or "lagging" by 70% of the experts as seen in Figure 5.

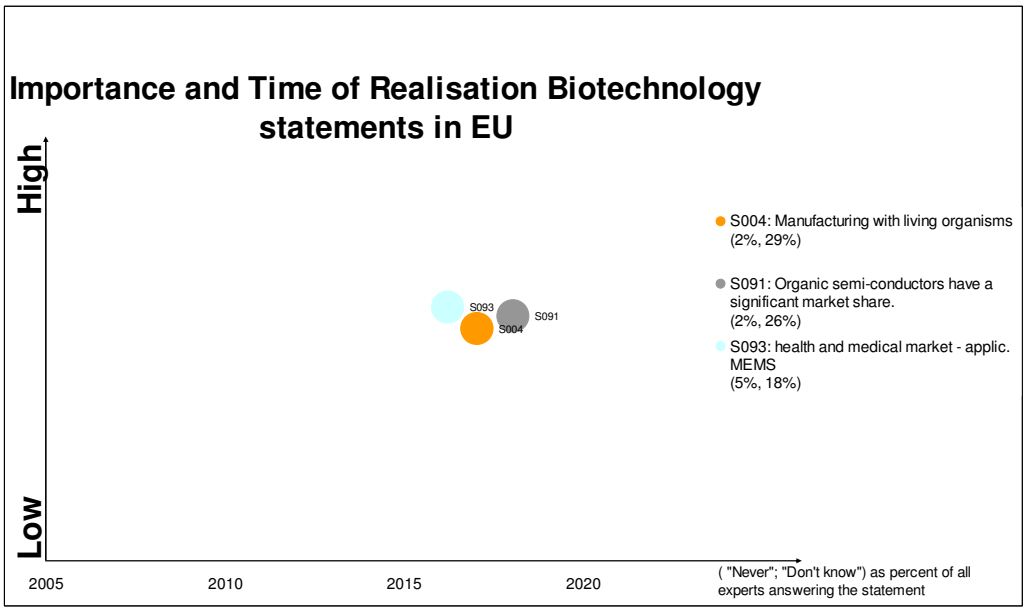



***Figure 7 Importance and time of realization biotechnology related statement of ManVis in EU***

Moreover, all of the biotechnology related statements are considered as having positive effect on living and working conditions. Minimum 45% of the experts believe that they will increase the living and working conditions. In addition to that, competitiveness and environmental quality are expected to improve. "Manufacturing

with living organisms" in particular is considered to have a significant positive effect on environmental quality and competitiveness. However, "regional differences" have an increasing trend. Moreover, "Manufacturing with living organisms" has a negative effect on employment as seen in Figure 10.

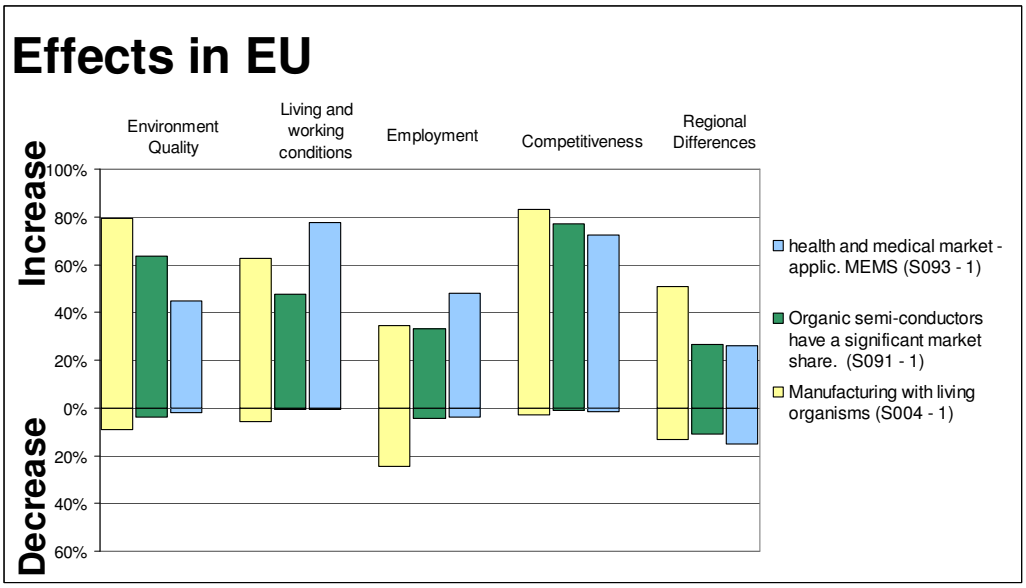



***Figure 8 Effects of biotechnology related statement of ManVis on EU***

### *4.2.3. Information Technologies*

Intelligent control (S001), human machine interface (S002), MEMs (S005), cobolts (S006), flexible automation (S007), customization (S014), electronic labels (S034), customization by software (S035), high automation (S045), automatic CNC programming (S064), virtual machine simulation (S065), NC software (S068), wireless communication (S069), customization ICT tools for end users (S079), virtual reality tools (S080), wireless electronic recharging (S088), non-optical semi-conductors (S090), organic semi-conductors (S091), MEMS in Health and Medicine (S093), High Speed Optical Communication (S094) are the statements about information technologies in the first round of the Delphi study of ManVis.

There are only six statements in which degree of expertise are considered as "low" or "very low" by 50% of the experts. These are cobolts (S006), NC software (S068), non-optical semi-conductors (S090), organic semi-conductors (S091), MEMS in Health and Medicine (S093), High Speed Optical Communication (S094). Degree of

expertise on the rest of the statements is considered as “high” or “very high” as seen in Figure 6.

About 50% of the experts think that EU is in “lagging” position on “non-optical semi-conductors (S090)”, “organic semi-conductors (S091)” statements. The rest of the statements are considered as “top”, “second” or “average” by at least 60% of the experts as seen in Figure 5.

Information technology related statements have time of realization between 2010 and 2020, especially concentrated in 2015. “Flexible automation (S007)” and “organic semi-conductors (S091)” statements are thought as having the latest realization time as seen in Figure 11 and in Figure 12.

On the other hand, importance of the virtual reality statement and automation related statements are considered as high. These are “Automatic CNC programming (S064)”, “virtual machine simulation (S065)”, “virtual reality tools (S080)”, “high automation (S045)” as seen in Figure 11 and in Figure 12.

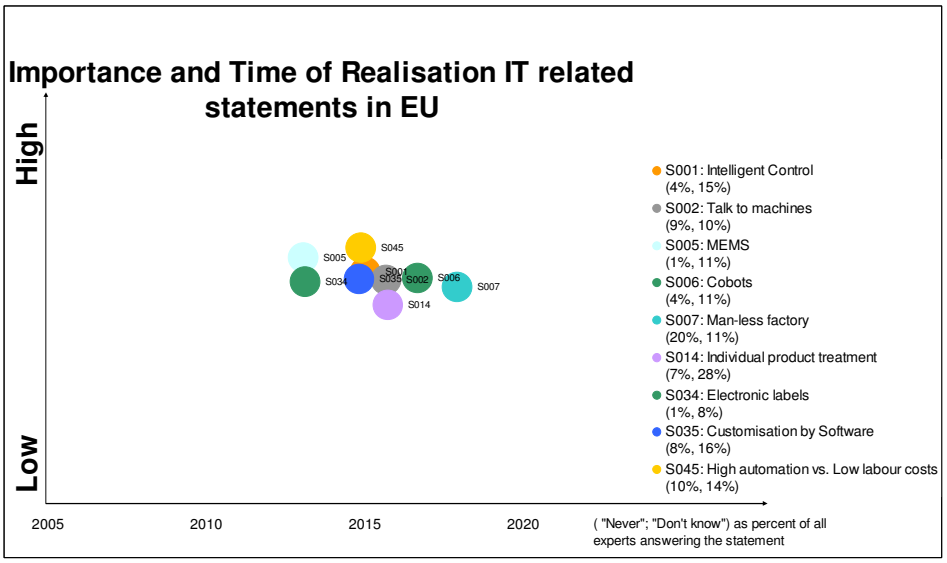



***Figure 9 Importance and time of realization IT related statement of ManVis in EU (1/2)***

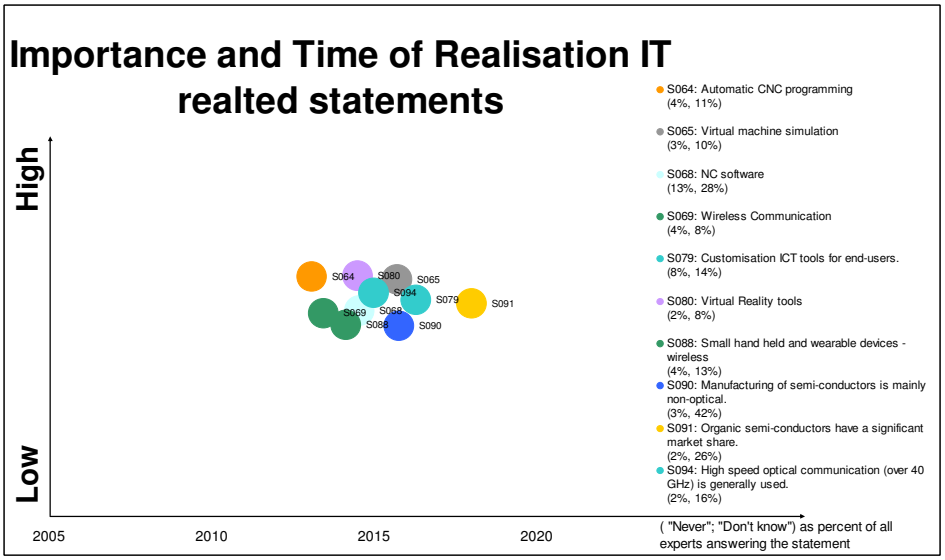



***Figure 10 Importance and time of realization IT related statement of ManVis in EU (2/2)***

The "Effects Graph" shows the percentage of experts assessing the assumption whether IT related statements increase or decrease environmental quality, living and working conditions, employment, competitiveness and regional differences in Figure 13 and Figure 14.

There is a consensus that all the IT statements have positive effect on living and working conditions. In addition to that, there is a consensus as far as competitiveness and environmental quality are concerned. “Intelligent control (S001)”, “human machine interface (S002)”, “MEMs (S005)”, “cobolts (S006)”, “flexible automation (S007)”, “customization by software (S035)”, “high automation (S045)”, “automatic CNC programming (S064)”, “virtual machine simulation (S065)”, “customization ICT tools for end users (S079)”, “virtual reality tools (S080)”, “organic semi-conductors (S091)" are considered to have significant positive effect on competitiveness. However, “regional differences” have an increasing trend. Particularly “intelligent control (S001)”, “human machine interface (S002)”, “MEMs (S005)”, “cobolts (S006)”, “flexible automation (S007)” statements have this positive effect on regional difference. Moreover, notably “cobolts (S006)”, “flexible automation (S007)” have negative effect on employment. Furthermore, “Intelligent control (S001)”, “human machine interface (S002)”, “MEMs (S005)”, “high

automation (S045)", "automatic CNC programming (S064)" statements have significant negative effect on employment, too.

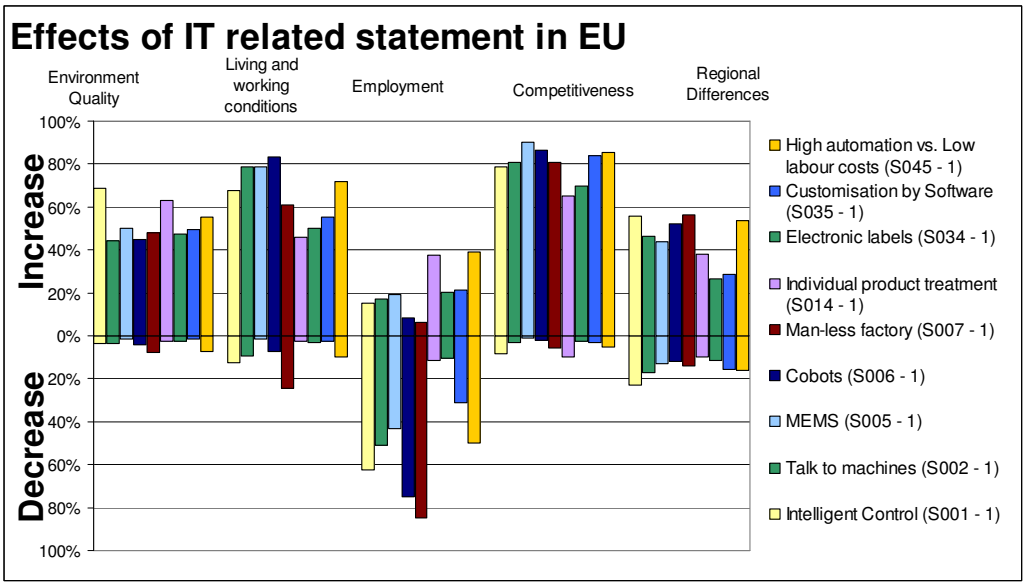



*Figure 11 Effects of IT related statement of ManVis on EU (1/2)*

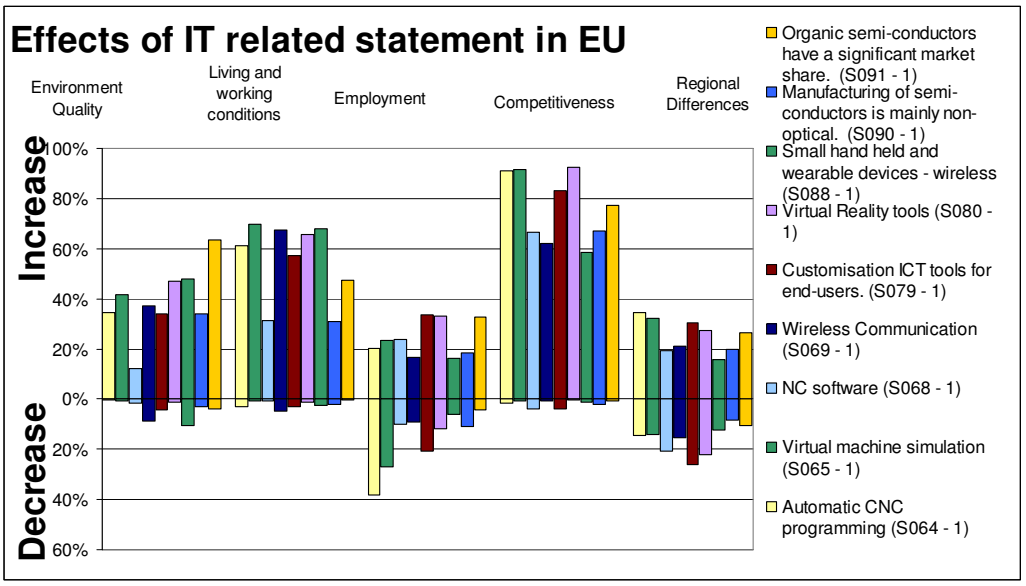



*Figure 12 Effects of IT related statement of ManVis on EU (2/2)*

### *4.3. Vision 2023*

The first foresight study of Turkey, Vision2023, was completed in 2003. It was based on expert group study and mostly on Delphi study. Eleven fields were identified as critical for Turkey.

1. Information technologies
2. Environment and sustainable development
3. Energy and natural resources
4. Construction and infrastructure
5. Chemistry
6. Machinery and material
7. Health
8. Defense, aero and space
9. Agriculture and food
10. Textile
11. Transportation and Tourism

This section summarizes converging technologies-related subjects in these eleven fields. The first part covers statements of the Delphi study; the second part contains panel reports, and the third part involves synthesis report statements.

#### *4.3.1. Delphi Study*

The directly connected fields and the corresponding converging technology such as direct connections between biotechnology and health, agriculture and food are examined in the first part of the technology field. The second part contains the statements of converging technologies in each technology field.

***Information technologies***

There are fifty-eight statements. Information technology field is directly related to one of the converging technologies; therefore, first of all it is divided into subfields as communication technologies, hardware, software, and multi media. The numbers of statements about communication technologies, hardware, software, and multi media are eleven, twenty-six, fourteen and seven respectively. High speed

communication networks, wireless communication systems such as WLAN (Wireless Local Area Network), GSM (Global System for Mobile Communications), GMPC (The Government Multipurpose Card) and diffusion of both subjects, use of high orbit and low orbit satellite system are concepts of communication technologies. There is a wide variety of concepts that are related to hardware such as medical devices, sensors in transportation system, sensors in agriculture, satellite, battery, adaptive systems and materials, organic based computers or elements of computer, integrated circuits, and CMOS (Complementary Metal-Oxide Semiconductor). Developing algorithms on cryptography, voice recognition and authentication, authorization mechanisms, developing remote control, increasing the use of networks and the Internet are the concepts of the software part. Compressing techniques, fooling senses, databases for cinema and television series are the concepts of multimedia.

Of these fifty eight statements, eleven are related to biotechnology, nine of them are related to cognitive science and two are related to nano technology. Biotechnology related statements are concerned with DNA based computer, direct connection with brain, monitoring of the human body, and improvement in medicine (statements: 27-30,32,48-53). Cognitive science related statements deal with the fooling of human sense, translation in two different human language or in between human and computer language, artificial intelligence, direct link between the brain and machine (statements: 14-16,18,22,23,29,43,44). Nanotechnology related statements involve creating micro devices as drug and monitoring the human body (statements: 33,48)

***Environment and sustainable development***

In this strategic technology field there are twenty seven foresight statements. In these statements three of them are related to information technologies, four of them are related to biotechnology, none of them is related to cognitive science, and one of them is related to nano technology.

Information technology related statements involve artificial intelligence systems. (statements: 1,4,9). Biotechnology related statements involve reduction in the use of plastic in different fields by biotechnological products, reduction of contamination

with the help of biotechnology, and creation of energy by biotechnological process (statements: 6,14,21,25). Nano technology related statements involve sensors (statement: 10).

***Energy and natural resources***

In this strategic technology field there are forty seven foresight statements. Of these statements, one is related to information technologies, two are related to biotechnology, and none is related to cognitive science and nano technology. The Information technology related statement includes artificial intelligence systems (statement: 32). Biotechnology related statements include use of biomass (statements: 2,20).

***Structures and infrastructure***

In this strategic technology field there are twenty nine foresight statements. Of these statements, two are related to information technologies, none is related to biotechnology, none is related to cognitive science and one is related to nano technology. Information technology related statements include artificial intelligence systems (statements: 17,26). The nano technology related statement includes reduction of friction forces (statement: 12).

***Chemistry***

In this strategic technology field, there are fifty two foresight statements. Of these statements, two are related to information technologies, five are related to biotechnology, none is related to cognitive science, and four are related to nano technology. Information technology related statements include design aid of IT and monitoring of chemical reactions (statements: 19,20). Biotechnology related statements include creation of medicine, monitoring and treatment of diseases and broken bones (statements: 13-16,37). Nano technology related statements include the production of polymeric material, medicine, and sensors (statement: 6,13,42,43).

***Machinery and material***

In this strategic technology field, there are sixty seven foresight statements. Of these statements, four are related to information technologies, three are related to biotechnology, none is related to cognitive science, and eleven are related to nano technology. Information technology related statements include artificial intelligence, design aid in simulation, wireless communication, and virtual reality (statements: 4,14-17). Biotechnology related statements include design of organic monitors, use of biofuel, and monitoring human body (statements: 8,37,51). Nano technology related statements include the production of nano scale devices, calibration, energy cells, sensors, reduction friction, and filtration of unwanted materials (statement: 11,19-21,27,40,47,64-67).

***Health***

Health is one of the titles directly related with biotechnology. There are five main subtitles. (1) Guarding, diagnosis, and treatment of the body with genetics, (2) cellular treatments, (3) discovery of new drugs, (4) therapeutic protein medicines, (5) bioinformatics devices and tools are the subtitles. The first subtitle includes research on understanding the genetics and its variations diseases, research on genetics epidemiology and structural genome technologies and improvement in the systems that determine pathogen using molecules. The research on root cells and their transplantation are the main concern of cellular treatments. Targeted drug discovery is the main subject of discovery of new drugs. Therapeutic protein drugs subtitle involves financing start-up companies for catching-up the sector. The research on bioinformatics devices and tools focuses on software development and computer aided diagnosis.

In this strategic technology field there are forty six foresight statements. Of these statements, eight are related to information technologies, three are related to cognitive science and one is related to nano technology and two are related to nanotechnology. Information technology related statements include artificial limbs and sensors, mobile health monitoring devices, modeling, simulation and design of biologic molecules and medicine (statements: 12-14,21,23,30,40,41). Cognitive

Science related statements include artificial limbs and sensors (statements: 12-14). Nano technology related statements include devices that sample DNA or other protein based structures without disintegration and development of devices that can intervene diseases inside veins (statements: 19,20).

***Defense, aero and space***

In this strategic technology field there are forty five foresight statements. Of these statements, fifteen are related to information technologies, two are related to biotechnology, two are related to cognitive science and eight are related to nano technology. Information technology related statements include control system of inhabitant vehicles, processing large amount of data, high speed communication, cyberspace security, fooling human senses (statements: 5,6,11-20,22-24). Biotechnology related statements include design of sensors for biological activities in and out of human body (statements: 10, 20). Cognitive Science related statements include fooling human senses (statements: 14,23). Nano technology related statements include the production of light weighted and high strength materials for vehicles, sensors such as ones on armor of warfighter or ones on the inhabitant vehicles for monitoring the body and environment (statements: 30,34-38,40,43).

***Agriculture and food***

Agriculture and food is another title directly related with biotechnology. There are seven main subtitles. (1) Stress tolerance in plants and functional food production, (2) diagnosis of plant diseases and biotechnology fighting, (3) production of qualified grain, seedling, sapling, (4) with the help of biotechnological process, raising economically valuable animals, (5) protection and definition of the gene sources of wild and domesticated animals, (6) use of vaccines and medicine for animals that are developed by genetic and biotechnological systems, (7) production of medicine by transgenetic technology.

Transgenetic, self cloning techniques and production of enriched vegetables are the subjects of stress tolerance in plant and functional food production. Development and diffusion of diagnosis biotechnology depended system for vegetable diseases are the main concern of the second subtitle. Improvement in genetic structure of the

vegetables that can be economically valuable with use of hybrid seeds and haploid is the concern of the production of qualified grain, seedling, and sapling. Use of biotechnological process such as production of embryo, transfer of embryo or manipulation of the gender is covered by the fourth subtitle. Preserving root or germinative cells or one scale large embryo and gamet by freezing technique, and gene mapping studies on animals are covered by the fifth subtitle. The sixth subtitle is related to resistant against animal based diseases and development of devices and tools for diagnosis of molecular and genetic diseases. The use of transgenetic animals to produce medicine through natural process of their bodies is the main concern of the last subtitle.

In this strategic technology field there are seventy three statements. Of these statements, three are related to information technologies, none are related to cognitive science or nano technology. Information technology related statements include senor, network system, and DNA chip technology (statements: 1,2,21).

***Textile***

In this strategic technology field there are forty statements. Of these statements, five are related to information technologies, five are related to biotechnology, none is related to cognitive science and three are related to nano technology. Information technology related statements include web based supply-demand system, CAD systems, wearable computers (statements: 29-31,34,38). Biotechnology related statements cover genetically manipulated fiber, and linen and hemp that have no anesthetic affect (statements: 1-5). Nano technology related statements include the production of intelligent cloth and wearable computers (statements: 34-36).

***Transportation and Tourism***

In this strategic technology field there are thirty three statements. Of these statements, thirteen are related to information technologies, two are related to biotechnology, and none is related to cognitive science or nano technology.

Information technology related statements include monitoring systems of flow in all kind of traffic, signaling systems of hardware and software, sensors that monitor

inside and close environment of the vehicles, sensors that monitor flow of traffic, software and hardware for these sensors, and Internet based mapping, reservation, and similar system (statements: 9,11,16-25,28). Biotechnology related statements include biology oriented fuel system (statements: 12,13).

### *4.3.2. Panel Report*

In the panels eleven subjects are reviewed and examined by experts between July 2002 and October 2003 (Tübitak, 2004). In these panel reports there are statements related to foresight on converging technologies. This section investigates technology activity subjects related to converging technologies in the panel reports. Information technology, chemistry, machine and material, health and medicine, defense, aero and space, agriculture and food panels have related subjects with converging technologies.

#### *Information technologies*

The information technology panel report (Tübitak, 2004) covers the technology activity subjects that are directly related to one of the converging technologies, and affects other converging technologies in these fields. Technology activity subjects of this panel are distance diagnosis, medical analysis and control, computers that do not require an additional education for use, information security, satellite application, forth generation mobile communication technologies in transporter systems, development broadband communication network, bioelectrical human computer interfaces, new systems in consumer electronic, production technologies of advanced and strategic components, and problem solving social applications. Technology fields are divided into three groups, such as, design (hardware) technologies, design (software) technologies, and production technologies.

Biotechnology has an important role in the production technology field with biological storage elements that enable the use of computers without additional education, building broadband communication network, bioelectrical human computer interfaces technology activity subjects.

Cognitive science, which leads to the improvement in the area of artificial intelligence that is viewed under the heading of design (software) technology, has an effect on titles such as distance diagnosis, medical analysis and control, bioelectrical human computer interfaces. Moreover, technology activity subject, computers that does not require additional education for use, is affected by both artificial intelligence and processing of natural language.

***Chemistry***

Chemistry panel report (Tübitak, 2003) states that information technologies have significant effects on the development of chemical and petrochemical production processes, which use alternative raw materials, factories capable of flexible production process that are rapid, compact and capable of rapid product changes.

Biotechnology has a significant role in chemical synthesis technology field having effects on technology activity subjects such as development of chemical and petrochemical production processes which use alternative raw materials. It also takes part in the development of production methods of high performance organic, inorganic, and composite materials, and in the development of high efficient environment friendly systems.

***Machinery and material***

There are ninety technology activity subjects in this panel report (Tübitak, 2003); therefore, their grouping was required: Namely, radical improvement in home comfort devices that cause a significant difference, hybrid vehicle, continuity of production of home comfort devices with environmental awareness, high strength ultra light materials, electronic-optic materials, traditional materials, vehicle seats and bodies, competency in production systems, intelligent machines, competency in general systems and service equipment especially for satisfying Turkey's needs.

Information technologies were in focus of the converging technologies in this panel. Simulation and modeling are considered as tools that will provide time reduction in the supply chain and investment. Computer aided design, MEMs, sensors application, rapid prototyping and embedded software are considered as leading

fields affecting automotive and house comfort technology activity fields (Tübitak, 2003).

One of the effective converging technologies in this panel is nano technology. The value of nano materials not only in the impulsive and repulsive forces fields but also in the automotive sector is pointed out. In automotive, house comfort and material fields are mentioned; however, as the importance based sorting is done in the panel, nano technology related statements were simply disregarded (Tübitak, 2003).

Biotechnology is taken into account just in hygiene and human health under house comfort subtitle (Tübitak, 2003).

***Health***

There are three subtitles in this panel report (Tübitak, 2003). Medical equipment, tools and materials group, medicine group, and health service group. In the health service group there is no technology activity subject that is related to NBIC subjects.

Production of medical and plastic consumable materials, minimal invasive treatments systems, development and production molecular biology and genetic consumable and their use in diagnosis, development of intelligent limbs and sensors, distance patient monitoring system, development of multi process monitoring devices, development of nuclear, biological and chemical sensors are declared as technology activity subjects of medical equipment, tools and materials group (Tübitak, 2003).

Technology activity subjects of the medicine group that are related to NBIC technologies are the production of recombinant molecules, targeting technologies with controlled oscillation and carrier systems, development of medical equipment for diagnosis and treatment, design of rational medicine and invention of active molecules, treatment of degenerative diseases in cell and genes (Tübitak, 2003).

In the field of biotechnology, only molecular biology and genetics are considered as having link to development and production molecular biology and genetically consumable products and their use in diagnosis by medical equipment, tools and materials group. On the other hand, biotechnology (pharmaceutics), genetic

engineering, bio engineering, technology of transdermal carrier systems, liposome technologies, technologies of viral and non-viral carrier systems are related to all technology activity subjects in medicine group (Tübitak, 2003).

In the information technologies such as sensors, microelectronic, production technology of electronic card, production technology of high density microelectronic and hybrid circuits, display technologies, fiber optic cable technologies, robotics, computer interfaces, programmable circuits and memories, application software are considered to be related to all subtitles except production of medical and plastic consumable materials by medical equipments, tools and materials group. In addition to that, medicine group considered robotics, software, MEMS, microelectronics, communication technologies as having weak links with almost all groups except rational medicine and invention of active molecules (Tübitak, 2003).

Nano technology is considered as having relation with all subtitles of medical equipments, tools and materials group and medicine group (Tübitak, 2003).

***Defense, aero and space***

There are six technology activity subjects in this panel report (Tübitak, 2003). Information technologies, biotechnologies and nano technology are considered to affect the technology activity subjects. However cognitive science is not pointed out significantly.

Information technologies are considered critical in such technology activity fields as, (1) reaching high quality of information service in all layers in between integrated systems to individual users in military and civil information communication in information management and in information and communication security, (2) having national technologies and products that satisfy military and civil needs and being competitive in international level, (3) having advanced sensors and technologies that are used in security systems and users in the level of physical and biological, (4) having technologies to improve efficiency of system-user interaction and system usage, (5) having technologies of robotic and inhabitant system that are used in military and civil purpose, (6) having technologies of satellite and launching

spacecraft for military and civil purpose, (7) having technologies of critical weapon, anti weapon for national defense (Tübitak, 2003).

Bio technology plays an important role in technology activity fields such as, (1) having advanced sensors and technologies that are used in security system and users in the level of physical and biological, (2) having technologies to improve efficiency of system-user interaction and system usage, (3) having technologies of critical weapon, anti weapon and defense for national defense (Tübitak, 2003).

Nano technology influences technology activity fields such as, (1) having technologies of robotic and inhabitant system that are used in military and civil purpose, (2) having technologies of critical weapon, anti weapon for national defense (Tübitak, 2003).

Cognitive science is not stated; however, there are related technologies activity fields such as, (1) reaching high quality of information service in all layers in between integrated systems to individual users in military and civil information communication in information management and in information and communication security, and (2) having technologies efficiency of system-user interaction and system usage. (Tübitak, 2003)

***Agriculture and food***

In this title only biotechnology and information technologies are pointed out significantly in this panel report (Tübitak, 2003). Nano technology is mentioned under expected technologies; however, there is no foresight statement that is related to nanotechnologies.

Biotechnology as a technology field has significant effects on creating new genotypes with classical amendment and biotechnological combination technology activity subjects. Moreover, it has effect on production of qualified grain, seedling, sapling, characterization of genetic resources and their storage, diversity of processed food and food process methods, fight with and integrated solutions to diseases and pests by protection, control and treatment techniques. In addition to that,

biotechnology has a slight effect on security and reliability of food, evolution of natural resources and wild life (Tübitak, 2003).

Information technologies have significant effect on only the use of information technologies in the remote sensors and early warning systems in agriculture and forestry. It has effects on creating new genotypes with classical amendment and biotechnological combination, diversity of processed food and food process methods and minor effects on characterization of genetic resources and their storage, and security and reliability of food (Tübitak, 2003).

***Textile***

Textile panel report (Tübitak, 2003) involves only information technology part of the converging technologies. There is a significant effect of information technologies on providing all kind of data and information flow in electronic media technology activity field. Efficient use of energy and environmental friendly technologies and computer aided weaving, design and production technology activity fields are affected by information technologies. It has minor effect on tuning of machines used in textile production without human intervention technology activity subject.

***Transportation and Tourism***

It is hard to tell the effects of converging technologies in this field with the help of this panel report (Tübitak, 2003). There is no directly written association between technology activity fields and converging technologies. Therefore, this report is not mentioned.

### *4.3.3. Strategy Reports*

There are nine strategy reports that are prepared for Vision2023 study.

1. Information and communication technologies.
2. Biotechnology and genetic technologies
3. Energy and environmental technologies
4. Material technologies
5. Mechatronics

6. Nano science and nano technologies
7. Design technologies
8. Manufacturing technologies
9. Defense, aero and space industry application suggestion

***Information and communication technologies:***

As the strategy report is directly related to one of the converging technologies, detailed analysis on this field is required. First part covers information technology related technology vision and the second part covers its relation to rest of the converging technologies.

Microelectronics, display production technologies, broadband technologies, image processing product technologies are mentioned in the prior fields of information and communication technologies in the strategy report. Microelectronics covers integrated circuits production, integrated circuit design, organic semiconductors and unordinary integrated circuits. Display production technologies involve OLED (Organic Light Emitting Diode) display units, FED (Field Emission Display) technology, Display projection technologies such as GRV (Grating Light Valve) and projection on retina technology. Optical band image sensors, Infrared image sensors, micro image sensors are comprised of image processing product technologies. Broadband technologies are related to broadband intensifier, broadband modulation and multiplexing technique, broadband networks, optical switching, optic-electronic multiplexing, fiber optic terminal and ending units (Tübitak, 2004).

Organic semiconductors, OLED technologies, projection on retina technologies are the fields that are related to biotechnology (Tübitak, 2004).

Nano technology is mentioned as a solution to the miniaturization of the chip technology (Tübitak, 2004).

***Biotechnology and genetic technologies***

As the strategy report is directly related to one of the converging technologies, detailed analysis on this field is required. The first part covers biotechnology related

technology vision and the second part covers their relation with rest of converging technologies.

There are four subtitles in this strategy report (Tübitak, 2004). Medical biotechnology and gene technology, agriculture biotechnology and gene technology, livestock technologies and gene technologies, and finally industrial biotechnology and gene technologies.

Medical biotechnology and gene technology has five targets. (1) Guarding, diagnosis, and treatment of the body with genetics that conduct research on understanding the genetics and its variation as a factor of diseases, research on genetic epidemiology and structural genome technologies and improvement in the systems that determine pathogen using molecules, (2) cellular treatments related to research on root cells and their transplantation, (3) discovery of new drugs, (4) therapeutic protein medicines that involve financing start-up companies for catching-up the sector, (5) bioinformatics devices and tools that focus on software development and computer aided diagnosis.

Agriculture biotechnology and gene technology has five targets. (1) Stress tolerance in plants and functional food production that covers transgenetic, self cloning techniques and production of enriched vegetables, (2) diagnosis of plant diseases and biotechnology fighting focus on the development and diffusion of diagnosis biotechnology depended system for vegetable diseases, (3) production of qualified grain, seedling, sapling that concentrate on improvement in genetic structure of the vegetables that can be economically valuable with hybrid seeds and haploid, (4) protection and defining the gene sources and their characterization of them with target genes that deal with founding of national institute of gene protection, (5) development of genetically manipulated organisms bio-security system that is related legislation in this field (Tübitak, 2004).

Livestock technologies and gene technologies have four targets. (1) Biotechnological process, raise economically valuable animals focuses on the improvement of genetic strain of livestock, (2) protection and definition of the gene sources of wild and domesticated animals, cold storage of gamete, embryo, and cells of the wild and

domestic animals, (3) use of vaccines and medicine for animals developed by genetic and biotechnological systems with the emphasis on rapid diagnosis and treatment of animal diseases, (4) production of medicine by transgenetic technology that concentrates on transgenetic animals to produce protein for treatment (Tübitak, 2004).

Industrial biotechnology and gene technologies have two targets. (1) Development of alternative energy sources that are related to hydrogen based fuel cells, (2) development of environmental friendly industrial manufacturing process that focuses on biocatalyst (Tübitak, 2004).

Information technology related statements are in medical biotechnology under target bioinformatics devices and tools (Tübitak, 2004).

***Energy and environmental technologies***

There are few statements about nano technology and there is no statement about the rest of the converging technologies. Nano technology is important for hydrogen based cells and water treatment technologies (Tübitak, 2004).

***Material technologies***

There are few statements about information technologies and nano technology and there is no statement about the rest of the converging technologies. Information technologies are considered as an important tool in the field of developments in magnetic, electronic and opto-electronic materials that involve nano technology as one of the affecting branch (Tübitak, 2004).

***Mechatronics***

This strategy report involves three subtitles; (1) generic technologies, (2) robotic and automation technologies, and (3) MEMs, NEMs (Nano Electro-Mechanical System) and sensors. There are statements about information technologies and nano technology and few statements about cognitive science and biotechnology under these subtitles (Tübitak, 2004).

Information technologies are covered in generic technologies as design technologies, communication technologies, computing technologies, embedded software, artificial neural networks and artificial intelligence. Information technologies related subjects such as embedded software, image processing are assigned as required fields of robotic and automation technologies. MEMs, NEMs and sensors interact with information technologies in application fields of MEMs, NEMs and sensors such as switches, hard disk reader head, etc (Tübitak, 2004).

Nano technology is covered in MEMs, NEMs and sensors. It affects all the fields that MEMS has effects on such as automotive, home comfort, health, defense, aero and space, environment, information technologies, process control and metrology, textile, and food (Tübitak, 2004).

Biotechnology is the affected field in this report. Biometric robots, artificial limbs, noninvasive diagnosis and treatment, monitoring are the stated fields that are affecting the development of biotechnology (Tübitak, 2004).

Cognitive science and Mechatronic have a parallel study on artificial intelligence. However, the intersection is not stated in the report (Tübitak, 2004).

***Nano science and nano technologies***

As the strategy report is directly related to one of the converging technologies, detailed analysis on these fields is required. The first part covers the nano technology related technology vision and the second part covers their relation to the rest of the converging technologies.

Seven fields (Tübitak, 2004) , such as (1) nanofotonic, nanoelectronic, nanomagnatism, (2) nanomaterial, (3) fuel cells and energy, (4) nanocharacterization, (5) nanofabrication, (6) quantum computing in nano scale, (7) nano-biotechnology are covered in the report.

Nanofotonic, nanoelectronic and nano magnetism have 7 targets: (1) Understanding the production process of nanostructures that are formed by semiconductors, (2) Research and development on measuring and analysis of produced nanostructures,

(3) research on physics of electronic, photonic and spintronic devices that are composed of nanostructures, (4) increasing variety of nanostructures that are oriented in electronic, photonic and spintronic applications and research on behavior of nanostructures in molecular scale, (5) Research on infrastructure of production of embedded electronic, photonic and spintronic nanostructure devices, (6) Production of nanostructure LED, laser and detector prototype and the development in their production method, (7) production of nanostructure integrated circuit prototype and development in their production method (Tübitak, 2004).

Nanomaterial has 3 targets: (1) multifunctional nanocomposite materials that are used in sensors, fuel cells, coating of automotive, smart textile product, (2) bio-inspired materials and catalysts that are used as artificial enzymes, molecular devices, and artificial photo synthetic systems, (3) nano-electronic and nano-mechanic devices with self-assembly process (Tübitak, 2004).

Fuel cells and energy have 1 target, which is storage of hydrogen with the help of nano technology and developing fuel cells (Tübitak, 2004).

Nanocharacterization has 4 targets: (1) Developing scanning probe microscope and able to manipulate atoms in room temperature, (2) Developing Atomic Force Microscope that can measure horizontal and vertical forces in fluid or vacuum with atomic resolution, (3) Improving Scanning Hall Probe Microscope in 5-10 nm precision, (4) Developing new generation Scanning Hall Probe Microscope/Scanning Probe Microscope (Tübitak, 2004).

Nanofabrication has 3 targets such as (1) Developing nano-press methods, (2) Obtaining 10 nm scale nanostructures using electron beam lithography, (3) Using nano-press methods in production of integrated circuits (Tübitak, 2004).

Quantum computing in nano scale has 5 targets: (1) Research on material properties such as magnetism, insulation, superconductivity in nano scale (2) Development of quantum algorithms able to use q-bit property of nanostructure, (3) Research and simulation of stationary current stages that can be used in nano tubes as q-bit and understanding decoherence property, (4) and experimental characterization of it, (5)

Development of quantum cryptology in nano scale applicable in military and commercial use (Tübitak, 2004).

Nano-biotechnology has 2 targets: (1) Development of rapid, high precision and high capacity protein and DNA diagnosis systems via nano technology, (2) Development of rapid scanning process that is used in defining active material of target oriented medicine with nanotechnology (Tübitak, 2004).

Information technologies are the affected field in this report. Development in micro electronics and quantum computing on nano scale are the key technologies. Especially Nanofotonic, nanoelectronic, nanomagnatism and quantum computing subjects have significant effects on changing the structure of a computer (Tübitak, 2004).

Biotechnology is the affected field, too. Development in nano scale provide opportunities for the medical sector such as developing target oriented medicine and high speed diagnosis tools (Tübitak, 2004).

***Design technologies***

Four fields, such as (Tübitak, 2004) (1) computer aided design and computer aided manufacturing, (2) virtual reality, (3) virtual prototyping, (4) simulation and modeling software are covered in this report. The strategy report is not directly related to one of the converging technologies; however, its content is close to Information Technologies; therefore, a detailed analysis on this field is required. The first part covers the information technology related technology vision and the second part covers their relation with rest of the converging technologies.

Information technologies which influence the development of software that are able to calculate engineering values of design, to analyze real world simulations, to calculate faster with optimization of algorithms, and to work in grid computing environment are affecting fields (Tübitak, 2004).

Biotechnology and nano technology affects a model for biologic process and simulation of new manufacturing process with new materials (nano materials) in this field (Tübitak, 2004).

Cognitive science is not mentioned directly; however, there are related statements such as verbal communication with computers (Tübitak, 2004).

***Manufacturing technologies***

There are few statements about information technologies and biotechnology and none about the rest of the converging technologies. Information technologies are considered as the affecting field of rapid prototyping and rapid manufacturing with design technologies. Biotechnology and Information technologies are considered to affect technologies in surface/midsurface, thin film, and vacuum technologies in bio compatible materials and MEMs (Tübitak, 2004).

***Defense, aero and space***

Information technologies, biotechnologies and nano technology are considered to have an effect on the subject. However, cognitive science is not mentioned.

Information technology covers data processing technologies, network technologies, multimedia technologies, data management technologies, web technologies, cybernetics, information war technologies, operation management and information system, synergy technologies of defense technologies, and health information network. However, there are two other technology activity subjects such as sensors, electronic and communication technologies and simulation/modeling/analysis and education technologies that are directly related to information technologies. Communication technologies, communication protocol technologies, communication process technologies, broadcast technologies, broadband and high speed Internet technologies, sensors technologies, actuators technologies, transmission/propagation circuit and device technologies, switching circuits and device technologies, signal processing technologies, computational information process circuits and device technologies, memory circuits and device technologies, integrated circuits mission system technologies, friendly/enemy target recognition systems, human computer

interaction technologies are covered in the first technology activity subject. Modeling/simulation/analysis technologies and mission education technologies are covered in the second technology activity subject. (Tübitak, 2004)

Biotechnology covers bioinformatics technologies, fuel technologies of biological mass, biosensors, bioproducts, biological anti-weapons and defense technologies, human health technologies, mineral reduction technologies, rehabilitation technologies of biologically contaminated areas, synthesis of complex structured molecules, environmental protection technologies, biological and physiological integrated technologies, medical treatment and support technologies, rapid microbiological diagnosis methods, rapid purifying and control of drinking water, and finally long term food storage techniques. (Tübitak, 2004)

Nano technology is covered under the title of unordinary systems, production methods and nanotechnology. In this title there are seven technology activity fields such as, nano phase material technologies, nanosensor technologies, nano actuators, nano switching device technologies, nano memory circuits and devices, nano weapon and ammunitions protection technologies, and lastly nano material technologies. (Tübitak, 2004)

# *CHAPTER 5*

# *SIMILARITIES AND DIFFERENCES*

In this section similarities and differences in visions about converging technologies are examined. In the first part similarities and differences on concept of vision statements are examined by comparing NBIC report and Vision2023 study. In this part nanotechnology, biotechnology, information technologies and cognitive science are not analyzed separately. Visionary statements of convergence of two, three or four of them are examined in both reports.

However, it is important not to forget that Vision2023 study is not special foresight study for converging technologies; therefore, some of the vision statements of NBIC report can not be easily noticed in Vision2023 study.

In the second part, answers of Turkish experts related to converging technology statements in ManVis Study are examined. The position of Turkey, degree of expertise, time of realization and importance, and the effects according to Turkish experts are shown and compared with overall result of ManVis Study.

## *5.1. NBIC vs. Vision2023*

### *5.1.1. Nano Technology and Biotechnology*

There are several application fields which involve biotechnology and nanotechnology; moreover, in most cases there will be a third or fourth technology for visionary projects. However, examined visions are the ones that are just affected by biotechnology and nanotechnology. These are listed in table-3.

***Table 3- NBIC vs. Vision2023 in Nanotechnology-Biotechnology convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Self-Monitoring of Physiological Well-Being and Dysfunction Using Nano Implant Devices | Monitoring of the human body |
| Nano-Medical Research and Intervention Monitoring and Robotics | Micro devices like drugs<br><br>Protein based structures without disintegration and development of devices that can intervene diseases inside veins |
| Projection on retina technologies | Projection on retina technologies |
| | Modeling for biologic process and simulation for new manufacturing processes with new materials such as nano materials |

"Self-Monitoring of physiological well-being and dysfunction using nano implant" devices title covers that biosensors, products of nano technology, enable real time monitoring biological activity; moreover, patients can learn how to control various body functions. Similarly, Chemistry and Information Technology Delphi Reports of Vision2023 include the statements such as creating micro devices like drugs. Moreover, Nano Technology Strategy Report improves this vision through developing rapid scanning process used in defining active material of target oriented medicine.

Nano-Medical Research and Intervention Monitoring and Robotics are about reducing the invasive effect of the surgery scalpel with nano-robots. Moreover, reducing the risk of post-surgery zone by monitoring patient with nano scale screening tools is another vision. In Health Delphi Report of Vision2023, nano

technology and biotechnology related statements involve devices that sample DNA or other protein based structures without disintegration and development of devices that can intervene diseases inside veins (statements: 19,20). In addition to that, according to Health Panel Report, the production of minimal invasive treatments systems is a technology activity subject of medical equipment, tools and materials group. Moreover, according to Mechatronics Strategy Report, biotechnology is the affected field in noninvasive diagnosis and treatment. In Mechatronics Strategy Report, monitoring of the human body is the stated point where biotechnology and Mechatronics overlap.

Warfighter education and training states that retinal projection view and sensors on the armor will provide monitoring data of the body. Information Technologies Strategy Report of Vision2023 covers projection on retina technologies, and Defense Aero and Space Delphi Report has statements involving production of sensors such as an armor of warfighter for monitoring the body and environment.

In addition to these similarities, Design Strategy Report of Vision2023 Study considered biotechnology and nano technology as effectual technology fields. Development in this field as a modeling for biologic process and simulation for new manufacturing processes with new materials such as nano materials are stated.

### *5.1.2. Nano Technology and Information Technologies*

Fields that emerge with the involvement of biotechnology and nanotechnology, without a third or fourth technology for visionary projects are listed in table-3.

***Table 4 - NBIC vs. Vision2023 in Nano Technology - Information Technology convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Inhabitant combat vehicle | Inhabitant system |
| Intelligent light and adaptive as a suit | Intelligent cloth and wearable computers |
| CBRE detection and protection | |
| Personal Sensory Device Interfaces | |

In NBIC Report inhabitant combat vehicle is described as well programmed software that controls the vehicle working on computer system that has very low processing time owing to nano processors, high speed communication systems with headquarter and durable shielding system that is a product of nano material. In Defense, Aero and Space Panel of Vision2023, “having technologies of robotic and inhabitant system that are used for military and civil purpose” is stated.

In NBIC Report, “warfighter education and training” states that storage and transfer of information about human and environment will be possible via light and adaptive as a suit. In Information Technologies Delphi Report of Vision2023, monitoring of the human body with intelligent suits is stated (statement: 48). In Textile Delphi Report there are nano technology related statements that involve production of intelligent cloth and wearable computers (statements: 34-36).

In addition to these similarities, NBIC report states two other visions. The first one is CBRE detection and protection that covers microfabricated sensor suites that will provide ample, affordable, error-free forewarning of chemical, biological, radiological, or explosive threat. The second one is Personal Sensory Device Interfaces that will enhance human abilities to perceive and communicate.

### *5.1.3. Nano Technology and Cognitive Science*

Convergence of Nano Technology and Cognitive Science has usually a third partner. For example, brain monitoring requires biotechnology as a third partner or creating artificial intelligence with nano chip technology requires Information technologies as a third partner.

There is one vision which involves the convergence of just two of them in NBIC report. Nano-Medical Research, Intervention Monitoring and Robotics are concerned with cognitive activities of the brain and bodily processes which are analyzed with the help of nano-enabled unremarkable tools.

There is no statement that is only related to nano technology and cognitive science in Vision2023 Study Reports.

### *5.1.4. Biotechnology and Information Technologies*

NBIC report and Vision2023 study cover several statements about convergence of biotechnology and information technologies but most of them are about convergence of the other technologies.

***Table 5 - NBIC vs. Vision2023 in Biotechnology and Information Technologies convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Manipulating DNA | |
| | Simulation and design of biologic molecules and drug |
| | DNA based computer |
| | Computer aid in drug design |
| | Mobile health monitoring devices |
| | Distance patient monitoring system |

In NBIC report, there is only one vision that covers only biotechnology and information technology. With the help of high speed computing and high volumes of storage area given by IT and the manipulating DNA that is provided by Biotechnology, it will be possible to control the genetics of humans, animals, and agricultural plants. Knowing the genetic diseases of unborn children is possible now, which will create a chance to cure them.

Vision2003 reports cover modeling, simulation and design in the magnitude of cell in Delphi Study, panel reports and strategy reports.

Health Delphi Report, Information technology and Biotechnology related statements involve modeling, simulation and design of biologic molecules and drug (statements: 30,40,41).

In addition to similarities, Vision2023 Reports covers more than one field where Biotechnology and Information Technology converge.

DNA based computer is stated in Information Technology Delphi Report (statements: 27-30), DNA chip technology is stated in Agriculture Delphi Report

(statement: 21), in Information Technology Panel Report, Information Technology and Biotechnology have role in production technology field with biological storage elements. Moreover, Organic semiconductors, and OLED technologies are mentioned in Information Technology Strategy Report.

Computer aid in drug design mentioned in Information Technology Delphi Report and diagnosis software stated in Biotechnology Strategy Report are included in Vision2023.

Moreover, in Health Delphi Report, mobile health monitoring devices are stated (statements: 21,23). In Health Panel Report, development of distance patient monitoring system, development of multi process monitoring devices are mentioned as technology activity subjects of medical equipment, tools and materials group.

### *5.1.5. Biotechnology and Cognitive Science*

Convergence of Biotechnology and Cognitive Science usually has a third partner. For example, preventing brain changes caused by sleep or deprivation has a third partner, nanotechnology, or learning how to learn requires information technologies as third partner. There is no vision that directly covers just two of them.

### *5.1.6. Information Technologies and Cognitive Science*

It is expected that the number of statements in this section will more than in the rest of two technology convergence statements as the artificial intelligence is one of the application field of these two technologies. However, NBIC report and Vision2023 study usually consider IT with nano computing or biotechnology oriented chips; therefore, there is always a third partner in this convergence.

The main goal of Learning How to Learn is how and why people learn. The goal to revolutionize science, mathematics, and engineering education will help to learn new skills and fundamental knowledge throughout life.

Warfighter education and training state that internal memory unit embedded into human will handle information. Computers with voice manipulation and language

translators will ease the interaction between computer and warfighter or between warfighter.

***Table 6 - NBIC vs. Vision2023 in Information Technology Cognitive Science convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Learning How to Learn | |
| Internal memory unit embedded into human | |

In NBIC report there are two visions that converges just two of these technologies.

Vision2003 reports cover none of the above visions in the magnitude of cell in delphi reports, panel reports or strategy reports. There is no vision statement that is directly related to just two of these technologies.

### *5.1.7. Nano Technology, Biotechnology and Information Technologies*

There are several statements on convergence of nano technology, biotechnology and information technologies but most of them are related to the convergence of the rest of the technologies.

***Table 7 - NBIC vs. Vision2023 in Nano technology, Biotechnology and Information Technologies convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Nano-bio processor | |
| | Biometric robots |

In NBIC report, there is only one vision that covers only three of them.

Nano-Bio Processor is one of the visions where nano technology, biotechnology and information technology converge without cognitive science. Its main concern is treatments with imitating human body by chips, which are programmed biological structures. The vision is the development of a “biological microprocessor” to synthesize and analyze biomolecules on nano platforms (liposomes, nanoparticles, selfassembled monolayers, and membranes) in fluids.

Vision2003 reports do not include the above mentioned vision in delphi reports, panel reports and strategy reports. However, in Mechatronics Strategy Report, biometric robots, noninvasive diagnosis and treatment where biotechnology and Mechatronics intersects are generally mentioned.

### *5.1.8. Nano Technology, Biotechnology and Cognitive Science*

Convergence of nano technology, biotechnology and cognitive science is related to convergence of the rest of the technologies.

There is only one vision that covers only three of them in NBIC report. Enhanced Tools for Creativity states that biologically inspired techniques, such as evolutionary design methods analogous to genetic algorithms, small-scale design activities in the order of nano, and understanding the complex structure of the brain promise new developments in such areas as visual language, personalized design, designing around defects.

Vision2003 reports do not cover the above vision in delphi reports, panel reports and strategy reports. Moreover, there is no vision that is directly related to just these three.

### *5.1.9. Nano Technology, Information Technologies, Cognitive Science*

There are several application fields that emerge via the convergence of nanotechnology, information technologies and cognitive science.

Guided by cognitive science, Virtual Environments deal with the marriage of nanotechnology to information technology, which can create realistic virtual environments and geographies and biotechnology will give opportunities to humans to experience new environments beyond the limits of human senses. It is possible to fool human senses as s/he is at remote locations or at imaginary environment. In Vision2003 studies, virtual reality is slightly examined in delphi reports, panel reports and strategy reports. Information Technology Delphi Report covers fooling of the human sense in the cinema sector (statements: 14-16). Defense, Aero and Space

Delphi Report has statements that involve fooling human senses as holographic images (statements: 20-21).

***Table 8 - NBIC vs. Vision2023 in Nano technology, Information Technologies, Cognitive Science convergence***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| Modeling the enemy's cognition processes | |
| Nano devices as computers | |
| Virtual Environments | Fooling of the human sense in the cinema sector |
| The Avatar Component | |
| The communicator / The Environmental Interface Component | |

Data linkage, threat anticipation, and readiness need information technologies to acquire a large volume of data against the potential enemy organization and to operate high speed data linkage among many databases that can be handled and analyzed with the help of nano technology. Understanding how the opponent analyzes and makes decisions will be possible through modeling the enemy's cognition processes.

Warfighter education and training cover some visions that are the product of three converging technologies. The information exchange with the computer can be fully interactive, involving speech, vision, and motion. Nano devices will be essential to store the variety of necessary information and to process the information in the millisecond time frames, which is necessary for real time interaction.

The communicator vision has three components, and two of them are related to these three fields of NBIC technologies. The first one is The Avatar Component, which represents the human in reality and in cyberspace as an autonomous computer agent, used in dangerous situations, resident nurse, perceives what personal avatar encounters, training avatar. The second one is The Environmental Interface Component that present individuals, and process their specifications. Each individual

receives fitting information for him/her. Learning and teaching strategies differ from individual to individual. In addition to that, virtual participation in a meeting or conference will be supported by this component. Moreover, the messages in these meetings will be structured in a way that would be the best for individuals' understanding.

### *5.1.10. Biotechnology, Information Technologies and Cognitive Science*

Convergence of Biotechnology, Information Technologies and Cognitive Science always needs the fourth partner, Nano technology. Developments in Information Technologies or Biotechnology usually have close interaction with Nano Technology. There is no vision that directly covers just three of them in both of the reports.

### *5.1.11. Nano Technology, Biotechnology, Information Technologies and Cognitive Science*

***Table 9 - NBIC vs. Vision2023 in all of the converging technologies***

| ***NBIC visions*** | ***Vision2023 visions*** |
|---|---|
| The Human Cognome Project | |
| Multimodalities for Visual- and Hearing-Impaired | Artificial limbs and sensors, |
| Brain-to-Brain and Brain-to-Machine Interfaces | Link between brain and machine with organic memory unit |
| Applications of brain-machine interface | |
| The communicator / The Individual Information Component | |
| Non-drug treatments for enhancement of human performance | |
| Education | |

Most of the NBIC Report statements are related to convergence of all fields.

In NBIC report, multimodalities for visual- and hearing-impaired covers the improvement on computer interface architecture such as holographic outputs, force-feedback, vibrotactile, vastly improved natural speech interfaces, and real-time close captioning. A person sitting in it will be able to move in any direction, horizontal or vertical, free from obstacles such as stairs. Functional artificial limbs, which might even be better than existing human limbs and artificial devices for hearing, vision, and cognitive abilities such as comprehension and memory, are the concern of NBIC. In Health Delphi Report of Vision2023, there are statements that involve artificial limbs and sensors (statements: 12-14). In addition to that, in Health Panel Report, development of intelligent limps and sensors are declared as technology activity subjects of medical equipment, tools and materials group.

Brain-to-Brain and Brain-to-Machine Interfaces: There are two visionary projects in this section:

a. Neurovascular approach: With the analogy of cardiovascular structure of the body and the use of this system in the treatment, neurovascular structure is considered as a hardware/software approach that allows a direct brain interface and the classification of its functional states to be used as a kind invasive approach.
b. Establishing direct links between neuronal tissue and machines that would allow direct control of mechanical, electronic, and even virtual objects as if they were extensions of human bodies is another visionary project. It enables the voluntary neural activity to control machines, electronics or even virtual objects

In Information Technology Delphi Report of Vision2023, there are statements concerning direct link between brain and machine with organic memory unit (statement: 29).

The Human Cognome Project is a project that needs full corporations of NBIC fields. Not only complete mapping of the connections in between the human brain and understanding, but also research on many fields of human endeavor, including education, mental health, and communications are the main concerns. Greater

understanding of the human mind will create opportunities to design technologies that are appropriate for human.

Applications of brain-machine interface have direct relation with all fields. Transmitting and receiving brain signals require nano-technology depended devices, processing these signal data require information technologies; understanding neural structure and measuring the brain electromagnetic activity depend on improvement in biotechnology, and the nature of the subject is directly related to cognitive science.

One of the three components of the communicator vision is a result of convergence of four NBIC areas. The Individual Information Component includes bioauthentication component which will save the time in initial socialization process by identifying humans in a society. It will work as a translator in a group. It will determine what stress levels, information density, and learning rates work best for the individuals; moreover, it will provide support to an individual in learning the topic, changing the mode of learning the best for that individual.

Non-drug treatments for enhancement of human performance need interaction of NBIC technologies to enable counterbalancing sleep deprivation and diminished alertness, improving physical and psychological performance, and increasing survivability rates from physical injury.

Liberal arts, engineering and science are the first evidence of convergence of nano-bio-info-cogs in education. This basic concept of merging science will affect the teaching process beginning from K-12 (Kindergarten through 12th Grade), to undergraduate and graduate education. Moreover, there will be another effect of NBIC on education: changing the tools and style of education with use of new devices.

There will also be a change in the curriculum of the K-12, which will have to cover the new technologies and developments through converging technologies such as in Biology. Courses in the content will have to be interdisciplinary.

Cognitive tools such as neurological-based technologies, and cognitive function measurement technologies that will be used in tandem with computer based attention and memory enrichment approach will improve the learning capacity of a child. Moreover, monitoring the brain activities of students during their engagement in educational material will provide data that will help to improve the education materials according to needs.

Tools of education will be modified as a true 24/7 educational resource. High-fidelity simulations will be available in telepresence and intelligent agents. Virtual reality technologies will provide a tool set such as digital game-based learning with meaningful game context, effective interactive learning processes including feedback from failure, and the seamless integration of context and learning. Widespread computer software will enhance academic cognitive abilities delivering brainwave biofeedback or neurofeedback for attention deficit disorder. Physiological feedback will be common in daily activities.

### *5.2. Turkey in ManVis*

In ManVis study, 192 Turkish experts participated. In the following pages their opinions about the statements that are related to nanotechnology, biotechnology, and information technologies are examined and compared with the overall results of the ManVis Study. In each technology field degree of expertise, lagging, time of realization and importance, and the effects are examined.

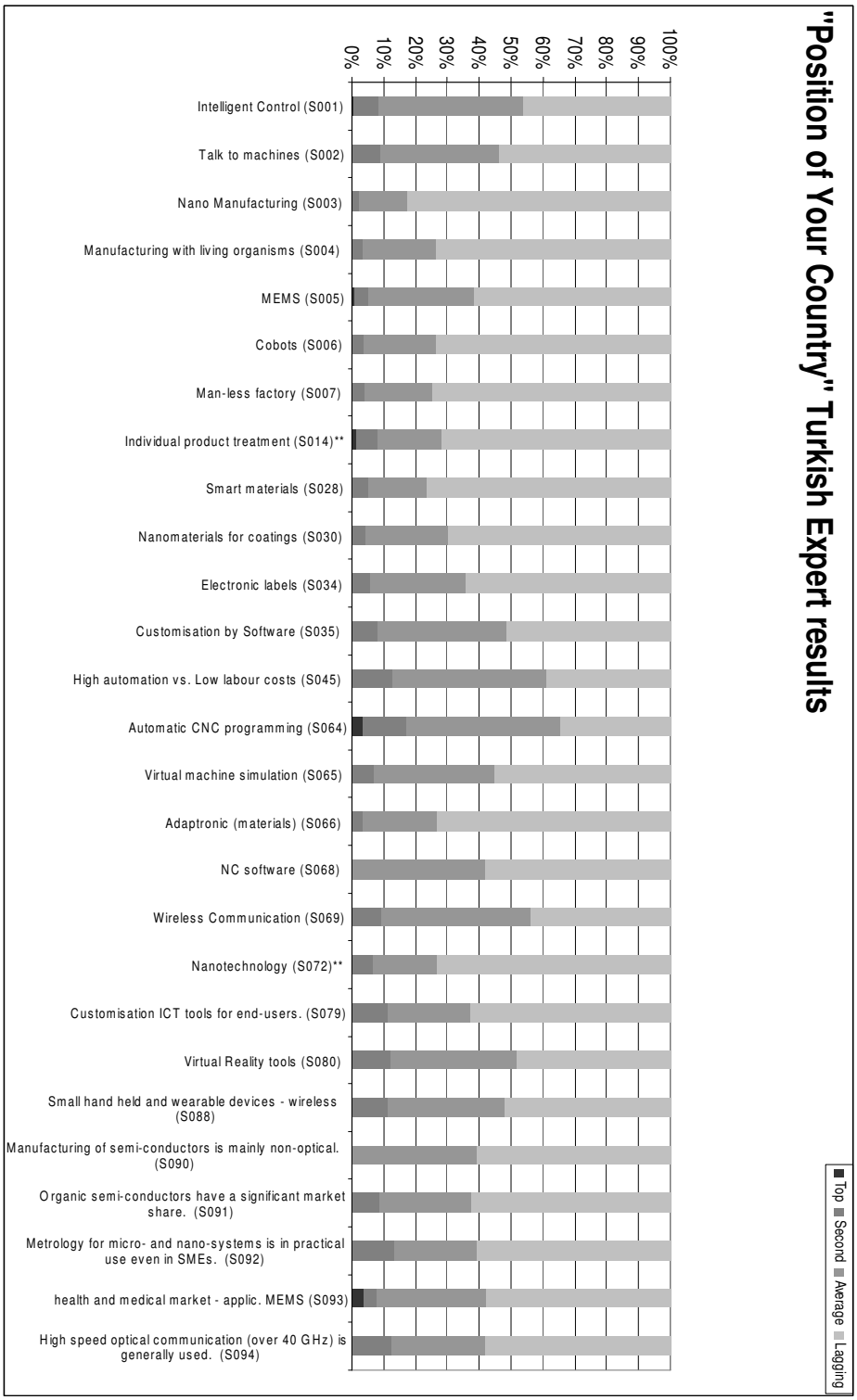



Figure 15 Position of Turkey according to Turkish experts

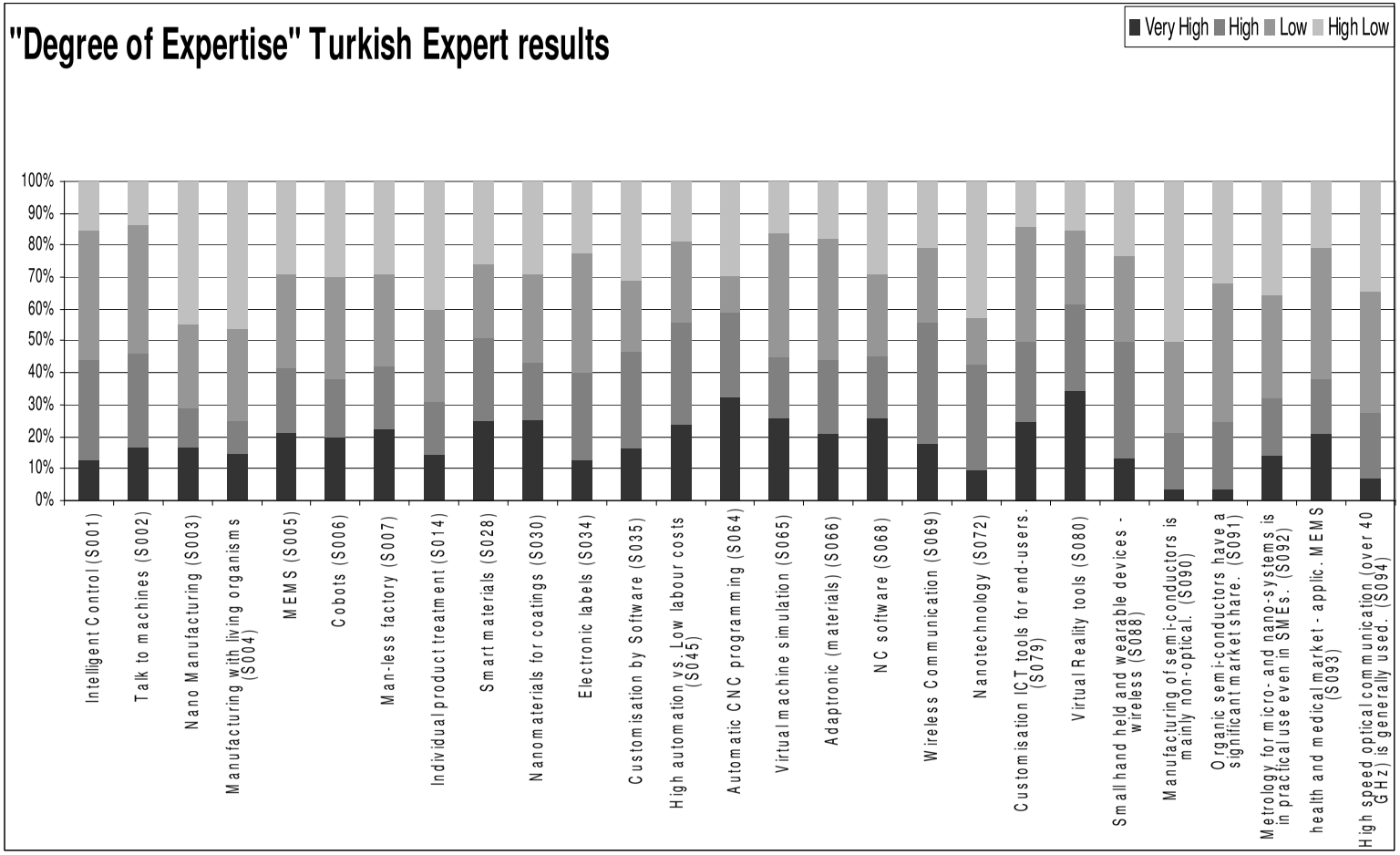



Figure 16 Degree of Expertise in Turkey according to Turkish experts

### *5.2.1. Nanotechnology*

In nanotechnology related statements, Turkish experts are positive in degree of expertise as seen in Figure 15. The summation of "very high" and "high" answers is more than 40% of Turkish experts. In statement "Nano manufacturing (S003)" 27% of the expert state that degree of expertise is very high. However, when all answers are considered, this statement has the least degree of expertise in nanotechnology related statement. On the other hand, opinion of 9% of Turkish experts on "nanotechnology (S072)" is "very high". 22% of all experts considered this statement as "very high".

According to Turkish experts in none of the nanotechnology related statement Turkey is on top. More than 90% of experts considered all nanotechnology related statements as "lagging" or "average" as seen in Figure 16.

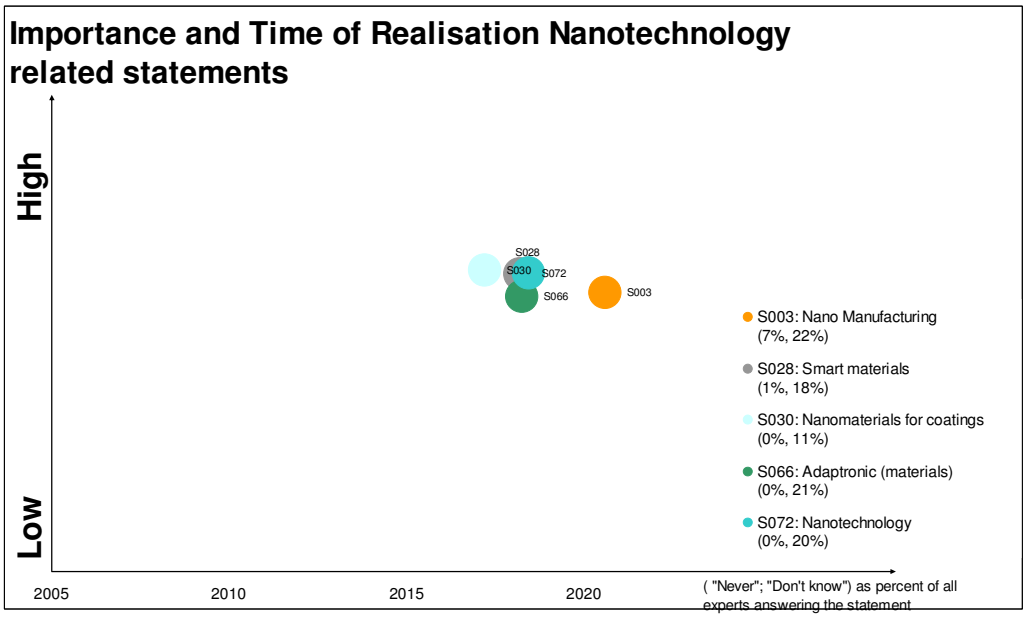



***Figure 13 Importance and time of realization nanotechnoly related statement of ManVis in Turkey***

According to Turkish experts the time of realization of the nanotechnology related statements is close to 2020 as seen in Figure 17. In overall answers of ManVis study, time of realization is assumed between 2015 and 2020. Importance of the technologies related to nanotechnology has similar placing in Turkish experts' opinions and all participant experts' opinions.

Moreover, all of the nanotechnology related statements are considered as having positive effect on living and working conditions. About 80% of the Turkish experts stated that they will increase the living and working conditions. On the other hand, opinions of 45% of all participant experts are positive. Moreover, competitiveness and environmental quality are considered as having an increasing trend by Turkish experts as well as overall experts' opinion. "Regional differences" have an increasing trend in "nano manufacturing (S003)"; however, the rest of the statements are considered as both increasing and decreasing effects, too. Moreover, "nano manufacturing" will decrease the employment as seen in Figure 18.

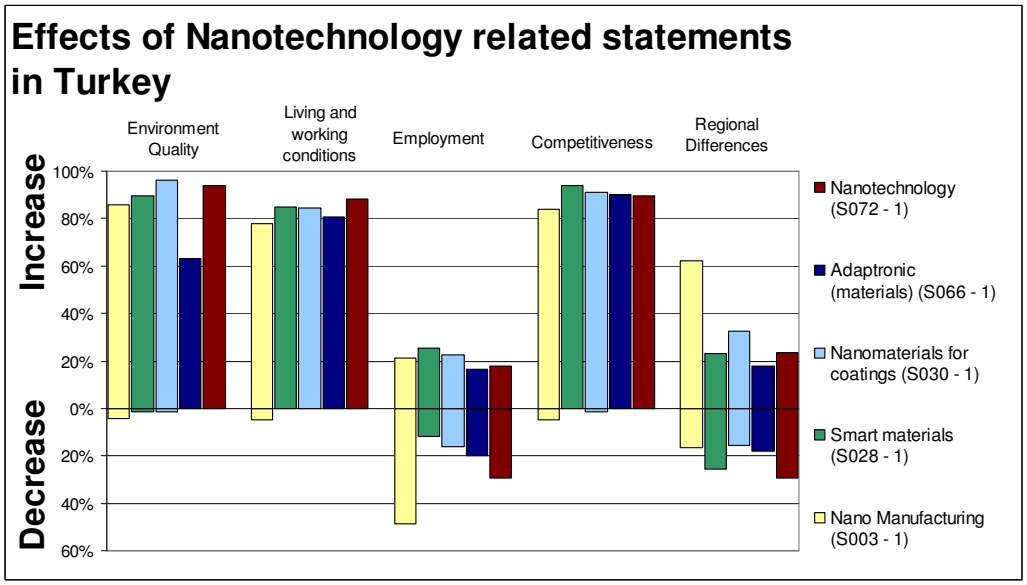



***Figure 14 Effects of nanotechnoly related statement of ManVis on Turkey***

### *5.2.2. Biotechnology*

The degree of expertise in "manufacturing with living organisms (S004)" and "health medical market – application of MEMs (S093)" are considered as "very high" by 21% of Turkish experts, and as "high" by 19% of Turkish experts, and 17% of Turkish experts respectively as seen in Figure 15. However, S004 statement is considered as "very low" or "low" by 75% of overall participant experts. According to 37% of all participant experts' opinion, S093 statement is thought to be "very high" and "high". The statement "Organic semi-conductors have a significant market share (S091)" is considered as "average" or "lagging" by 75% overall experts.

However, percentage of all participant experts who believe this statement is “very high” and “high” is 20% and 28% respectively.

In the position of your country question, the biotechnology related statements are believed to be “top” or “second” by less than 10% of Turkish experts. However, in S091 statement is considered as “second” by 8% of Turkish experts as seen in Figure 16.

Turkish expert assumed the time of realization of the biotechnology related statements between 2015 and 2020. There is a difference in the time of realization of S004 and S091. According to Turkish expert, S004 statement has the realization time after the realization of S091 statement. Importance of the technologies related to biotechnology has similar placing in Turkish experts’ opinions and all participant experts’ opinions as seen in Figure 19 and Figure 20.

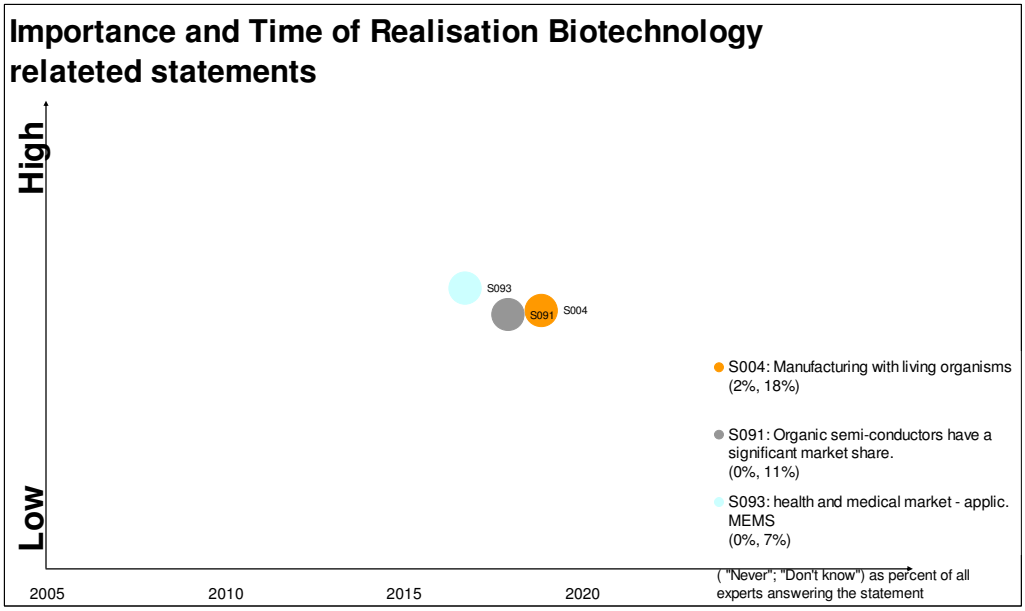



***Figure 15 Importance and time of realization biotechnology related statement of ManVis in Turkey***

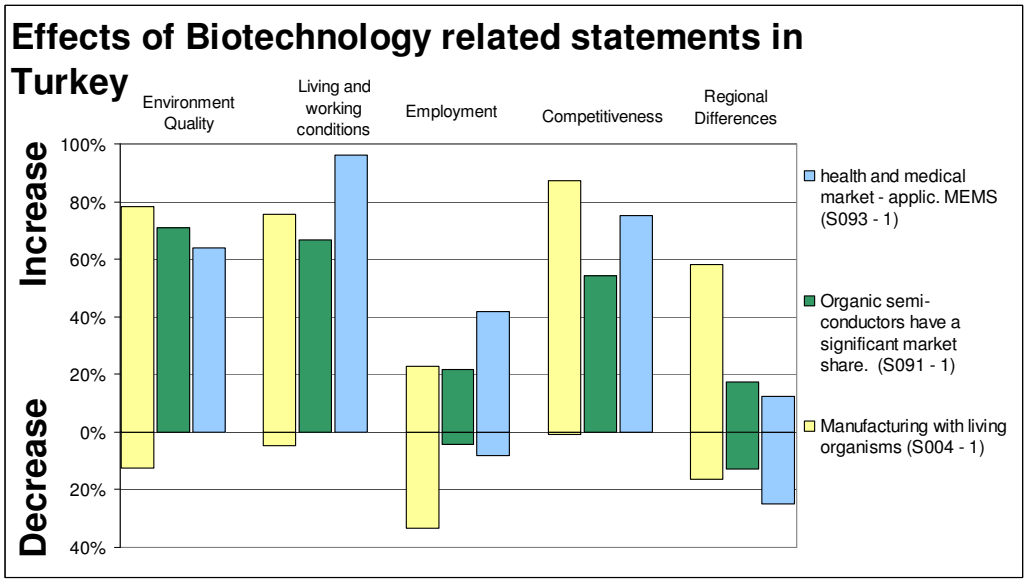



***Figure 16 Effects of biotechnology related statement of ManVis on Turkey***

Moreover all of the biotechnology related statements are considered as having positive effect on living and working conditions as seen in Figure 20. Especially, S093 statement is considered as having significant effects on the living and working conditions. Opinions of all participant experts are about 20% less than Turkish expert opinion in this respect. Moreover, competitiveness and environmental quality are considered as having an increasing trend by Turkish experts as well as all participant experts. However, effect of S091 is considered higher by overall experts than by Turkish experts. "Regional differences" has an increasing trend in S004 statement; however, the rest of the statements are considered as having both increasing and degreasing effect, too. S091 and S093 statement are considered to have positive effect on employment.

### *5.2.3. Information Technologies*

There are only five statements on which degree of expertise are considered as "high" or "very high" by 50% of the experts as seen in Figure 15. These are talk to machine (S002), high automation (S045), automatic CNC programming (S064), wireless communication (S069), virtual reality tools (S080). However, more than 70% of the experts considered that degree of expertise on "non-optical semi-conductors (S090)",

"organic semi-conductors (S091)" and "high speed optical communication (S094)" statements is "low" or "very low".

More than 70% of Turkish experts stated that position of Turkey is not "top" or "second" or "average" as seen in Figure 16. Moreover, there are only three statements which are considered as "top"; however, less than 5% of the Turkish experts are of this opinion. About 40% of the experts consider "high automation (S045)", and "automatic CNC programming (S064)" as "lagging". However, usually 50-60% of the experts view the rest of the statement as "lagging".

On the other hand, about 50% of all participant experts consider "non-optical semi-conductors (S090)", "organic semi-conductors (S091)" statements as "lagging". The rest of the statements are judged as "top", "second" or "average" by minimum 60% of the expert.

Information technology related statements have time of realization between 2010 and 2020, especially concentrated between 2015 and 2020. "Electronic Label (S034)", "Automatic CNC programming (S064)", "wireless communication (S069)" statements are thought as having the earliest realization time as seen in Figure 21 and Figure 22.

On the other hand, "individual product treatment (S014)" is thought as the least important in all IT related statement by Turkish experts. Moreover, this statement has the highest ratio of "don't know" answer among Turkish experts.

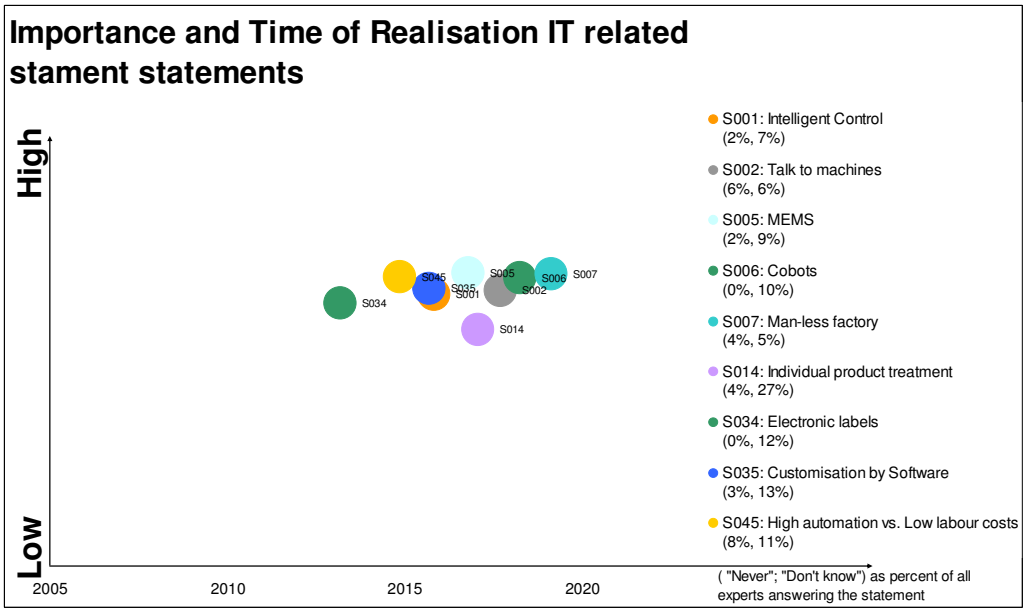



*Figure 17 Importance and time of realization IT related statement of ManVis in Turkey (1/2)*

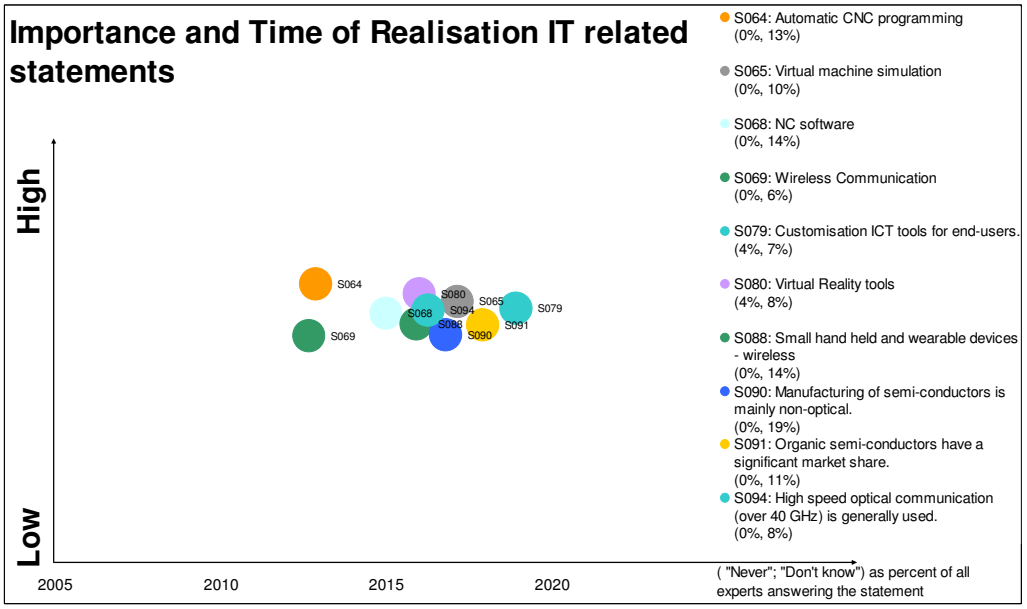



*Figure 18 Importance and time of realization IT related statement of ManVis in Turkey (2/2)*

There is a consensus that the IT statements have positive effect on living and working conditions as seen in Figure 23 and Figure 24. However, the ratio of Turkish experts on positive effects of "NC software (S080)" statement on living and working condition is somehow lower than that of other statements. In addition to that, there is a consensus as far as competitiveness and environmental quality are concerned. Though, less than 60% of Turkish experts thought that "wireless communication

(S069)", and "organic semi-conductors (S091)" statements have positive effect on competitiveness. However, "regional differences" has an increasing trend, particularly "Intelligent control (S001)", "human machine interface (S002)", "MEMs (S005)", "cobolts (S006)", "flexible automation (S007)" and "high automation (S045)" statements have increasing effect on regional difference. Moreover, notably "cobolts (S006)", "flexible automation (S007)" have decreasing effect on employment. Furthermore, "Intelligent control (S001)", "human machine interface (S002)", "MEMs (S005)", "high automation (S045)", "automatic CNC programming (S064)", "virtual machine simulation (S065)" statements have significant decreasing effect, too.

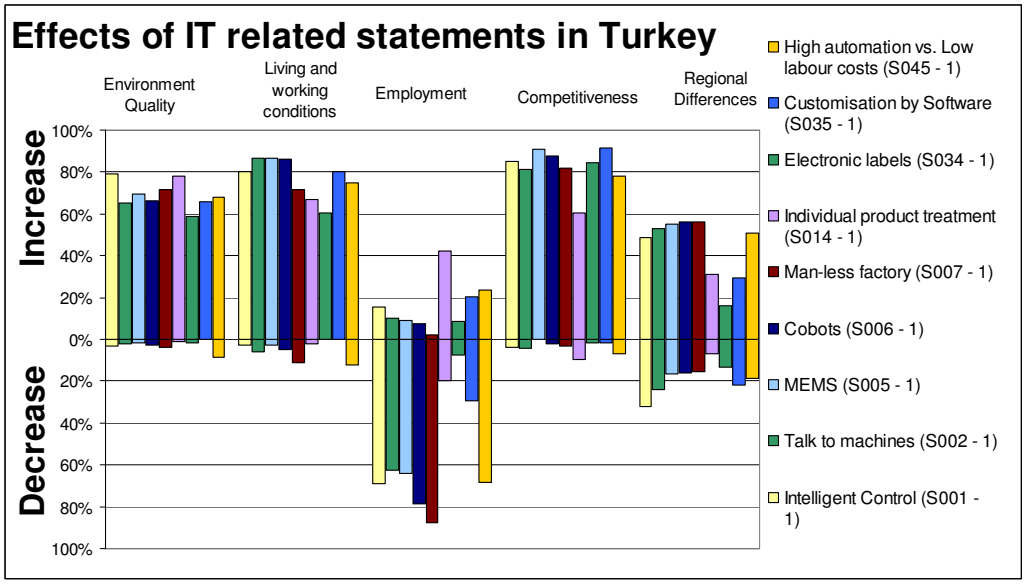



***Figure 19 Effects of IT related statement of ManVis on Turkey (1/2)***

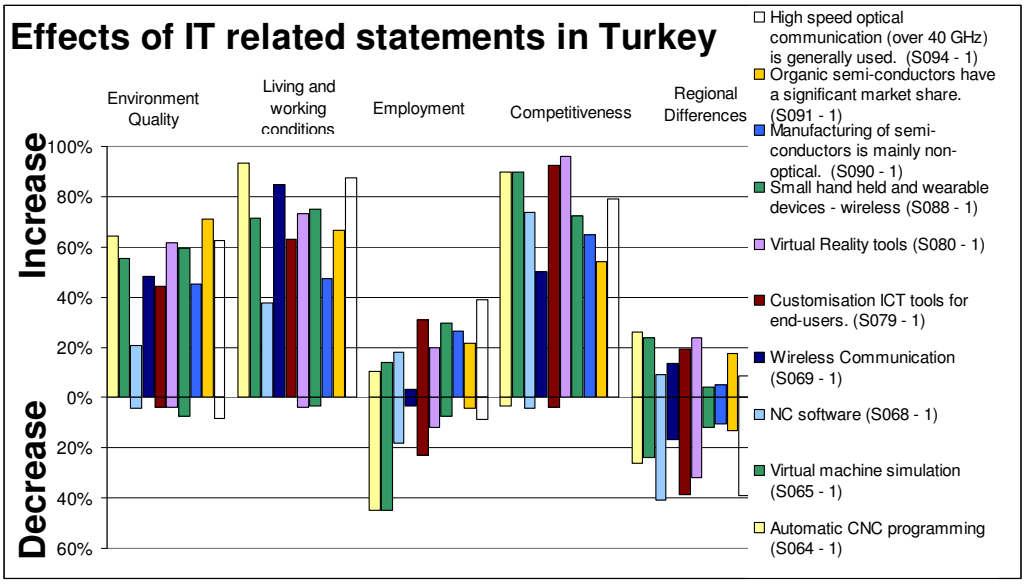



*Figure 20 Effects of IT related statement of ManVis on Turkey (2/2)*

# *CHAPTER 6*

# *CONCLUSION*

The main prospect of converging technologies is enabling each other just as an innovation in nanotechnology enabling biotechnology to create new imaging technologies; solving secrets of DNA gives a new vision to information technology; studies on computer language manipulates learning concept in cognitive science. There are foresight studies that are related to converging technologies in the USA, Canada, and EU in recent years.

In Turkey, there is only one foresight study, and it is about national foresight tough it is not directly addressing converging technologies: Vision2023. Therefore, it is imprudent to deny the advanced position of the American NBIC report as far as the converging technologies are concerned. However, as a national foresight study, Vision2023 should have covered these technologies that would shape the future of society as well as the points it has taken into consideration.

When compared to Vision2023, NBIC report is a well prepared document about converging technologies with expert group studies. There are some visions in NBIC report that are not mentioned in Vision2023 study. These are CBRE detection and protection, personal sensory device interfaces, manipulating DNA, learning how to learn, internal memory unit embedded into human, nano-bio processor, modeling the enemy's cognition processes, nano devices as computers, virtual environments, the communicator, the Human Cognome Project, multimodalities for visual- and hearing-impaired, brain-to-brain and brain-to-machine interfaces, applications of brain-machine interface, the communicator, non-drug treatments for enhancement of human performance, and education. A detailed investigation shows that twelve of

these seventeen visions are related to cognitive science. The remaining five are nano technology oriented visions.

Cognitive science in Turkey is in a miserable situation. There are only two graduate programs that are named as cognitive science in Turkish universities. In addition to that, these programs have no direct relation to a neuroscience department of medical schools. Although, there are departments of computer science or engineering in these universities to support the artificial intelligent studies, the main study fields of these cognitive science programs are linguistics and psychology.

On the other hand, there are state universities that invest in nanotechnology related subjects in Turkey. Research centers are nesting in private universities and technocenters. Moreover, firms make investments in research on nanotechnology.

Furthermore, according to ManVis Study Turkish experts are not hopeless about the future of nanotechnology field. In all nanotechnology related statements, ratio of "very high" and "high" does not differ more than 10% from total participants' opinion in ManVis Study. However, according to Turkish experts, Turkey is 5 years behind the expectations of EU in terms of the time of realization of nanotechnology related statements.

Biotechnology in Turkey has an increasing trend in number of firms. In addition to that, universities and research centers in Turkey have significant effect in this field.

Furthermore, some visions that are mentioned in Vision2023 study are not emphasized in NBIC report. Such visions include biometric robots, simulation and design of biologic molecules and drug, DNA based computer, computer aid in drug design, mobile health monitoring devices, distance patient monitoring system, modeling for biologic process and simulation for new manufacturing processes with new materials such as nano materials. Of these eight visions, seven are related to biotechnology. There are statements that are different from NBIC report, and all of them are related to biotechnology. It can be considered as a sign of a strong vision in this area.

In ManVis study, the position of Turkey and expertise of Turkish scientists in biotechnology related statements are believed to be very good by Turkish experts. According to more than 90 % of them, Turkey is in “average” or “lagging” position in biotechnology related statements. However as far as the level of expertise is concerned, more than 60 % of them think that degree of expertise in Turkey is “low” or “very low”.

Information technology in Turkey cannot be examined by number of firms, research centers or programs in universities since these cannot be considered as a sound indicator of where a country is in the field. However, according to OECD data, Turkey is in average position among 102 countries. Nevertheless, one needs a sound measurement device to find out the place of the country in the future in the given field. NBIC report can be considered as a reliable reference point,

NBIC report and Vision2023 study have similar statements that are related to all of the technology fields. These statements are especially related to information technology such as monitoring human body, intelligent suits or armors, inhabitant combat vehicle, retinal projection, virtual reality, artificial limbs, machine brain connection.

In ManVis Study, according to more than half of the Turkish experts, the position of Turkey is “lagging”. Expertise level in Turkey is thought as average by Turkish experts. In some statements, more than 50% of the experts thought that expertise level is “high” or “very high”; conversely in some statements more than 50% of them thought that level of expertise is “low” or “very low”. There is no classification in these fields.

In conclusion, there is a growing concept that is named as converging technologies and Turkey is not in a good position in the related fields of converging technologies. If necessary measures and actions are not defined and taken, lagging will increase.

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## *APPENDICES*

All the appendices are computer related document therefore they are in the CD that is at the back of the thesis. Appendix A is the Delphi Result of the Vision2023 Study in a “pdf” file and Appendix B is ManVis Study data and result in “xls” file.