Ümran ATABAŞ

A STUDY FOR TRAINING AND RAISING AWARENESS OF ELEMENTARY SCHOOL STUDENTS ABOUT NANOTECHNOLOGY AND BIOTECHNOLOGY SUBJECTS

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Umran ATABAS

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APPROVAL PAGE

This is to certify that I have read this thesis written by Umran ATABAS and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Biology.

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M.S. Thesis-Biology
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Supervisor: Prof. Dr. Fahrettin GUCIN

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ABSTRACT

The purpose of the study is to raise awareness of elementary school students and to train them about nanotechnology and biotechnology subjects, and to encourage educators in integrating these subjects to curriculum. Nanotechnology and biotechnology are new and key technologies. Nanotechnology and biotechnology are developing and spreading with a great speed and nearly all of the countries are making great investments in these technologies. Consequently, education and raising awareness of public about these technologies gained great importance. Students in the present are potential workers and consumers of these new technologies, and schools are key factor to raise awareness about advantages and potential risks of these young technologies. We prepared nanotechnology and biotechnology lesson plans and students participated in nanotechnology lessons in a public school. We worked with 47 5^{th} grade students. Effects of the study are evaluated with interviews and observations in this qualitative study. Interview answers of the students were analyzed through developing themes with content analysis method. The themes were, “What is Nanometer?”, “I Heard It for the First Time”, “Became Interested”, “Manipulative Characteristic of Matters”, “Atoms”, “Future”, “Smallness”, “Easiness-Simplify”, “Modeling from Nature”, “Science and Technology”, “Hydrophilic-Hydrophobic (Permeable or Repellent Water)”, “Self-cleaning”, “Can Nanotechnology be Harmful?”. At the end of the study we concluded that students are very interested and motivated against the courses and they can easily learn the subjects.

Key Words: Education, Nanotechnology Education, Biotechnology Education, Science and Technology, Nanotechnology, Biotechnology, Curriculum Development

İLKÖĞRETİM ÖĞRENCİLERİNİ NANOTEKNOLOJİ VE BİYOTEKNOLOJİ KONULARINDA EĞİTMEYE VE BİLGİLENDİRMEYE YÖNELİK BİR ÇALIŞMA

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ÖZ

Bu çalışmanın amacı ilköğretim (ilkokul ve ortaokul) öğrencilerini nanoteknoloji ve biyoteknoloji konularında eğitmek, bilinçlendirmek ve bu konuları müfredata entegre etme konusunda eğitmenleri cesaretlendirmektir. Nanoteknoloji ve biyoteknoloji yeni ve stratejik öneme sahip teknolojilerdir. Bu teknolojiler hızla gelişmekte ve yayılmakta, neredeyse tüm ülkeler bu alanlarda büyük yatırımlar yapmaktadır. Dolayısıyla bu teknolojilerin eğitimi ve bu konularda toplum bilinci kazandırmak büyük önem kazanmıştır. Bugünün öğrencileri yarının potansiyel nanoteknoloji ve biyoteknoloji tüketicileri ve çalışanlarıdır ve okullar bu teknolojilerin faydaları ve riskleri ile ilgili toplum bilinci oluşturmada anahtar öneme sahiptir. Bu nitel çalışmada nanoteknoloji ve biyoteknoloji ders planları hazırlanmış ve nanoteknoloji ders planları bir devlet okulunda uygulanmıştır. Araştırma 47 tane 5. sınıf öğrencisi ile gerçekleştirilmiş, sonuçlar röportaj ve gözlemlerle değerlendirilmiştir. Röportaj cevapları tema analizi yöntemiyle analiz edilerek, “Nanometre Nedir?”, “İlk Kez Duyuyorum”, “İlginç Olmak”, “Maddelerin Özelliklerini Değiştirmek”, “Atomlar”, “Gelecek”, “Küçüklük”, “Kolaylık-Kolaylaştırma”, “Doğadan Örnek Alma”, “Bilim ve Teknoloji”, “Su Geçirirlik-Su Geçirmezlik”, “Kendi Kendini Temizleme”, “Nanoteknoloji Zararlı Olabilir mi?” temaları oluşturulmuştur. Öğrencilerin derslere karşı yüksek motivasyona sahip ve çok ilgili oldukları, konuları rahatlıkla öğrenebildikleri sonucuna ulaşılmıştır.

Anahtar Kelimeler: Eğitim, Nanoteknoloji Eğitimi, Biyoteknoloji Eğitimi, Bilim ve Teknoloji, Nanoteknoloji, Biyoteknoloji, Müfredat Geliştirme

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION

AFM	Atomic Force Microscope
CNT-FED	Carbon Nanotube Based Field Emission Displays
DoA	United States Deparment of Agriculture
DoD	United States Department Of Defence
DoE	United States Department of Energy
DoJ	United States Department of Justice
IST	Information Society Technologies
OLED	Organic Light Emitting Diodes
NASA	National Aeronautics and Space Administration
NIST	United States National Institute of Standards and Technology
Nm	Nanometer
NNI	National Nanotechnology Initiative
NSF	National Science Foundation
NST	Nanoscience and Technology
QoL	Quality of Life in Europe
SEM	Scanning Electron Microscope
STM	Scanning Tunneling Microscope
TEM	Transmission Electron Microscope

CHAPTER 1

WHAT IS NANOTECHNOLOGY?

1.1 SIGNIFICANCE OF THE STUDY

As a new field, nanotechnology has become a center of interest, thanks to its significant promises since the late 90's. Experts have compared the technological breakthrough of nanotechnology with silicon and plastic, their effects on society and the wide range of new products, which emerged from their usage (Luther, 2004).

Different from substantial areas that have commercial effects developing around core discipline areas; nanotechnology is identical with its interdisciplinary structure and predominance of research and technological innovations at the frontiers of science and engineering. It has a very important role in inter-disciplinary research, whose discoveries and inventions promise to have powerful commercial and societal impact (Tiwari and Chattopadhyaya, 2004). This new "small" method of manipulating materials guide us for emerging young research areas and improvement of new products that are already available on the commercial market (Luther, 2004). We have already seen its effects on commercial areas like electronics, materials and coatings, catalysis, and some areas like biotechnologies, mechanical technologies, and other fields are expected to show significant improvement in the near future (Tiwari and Chattopadhyaya, 2004).

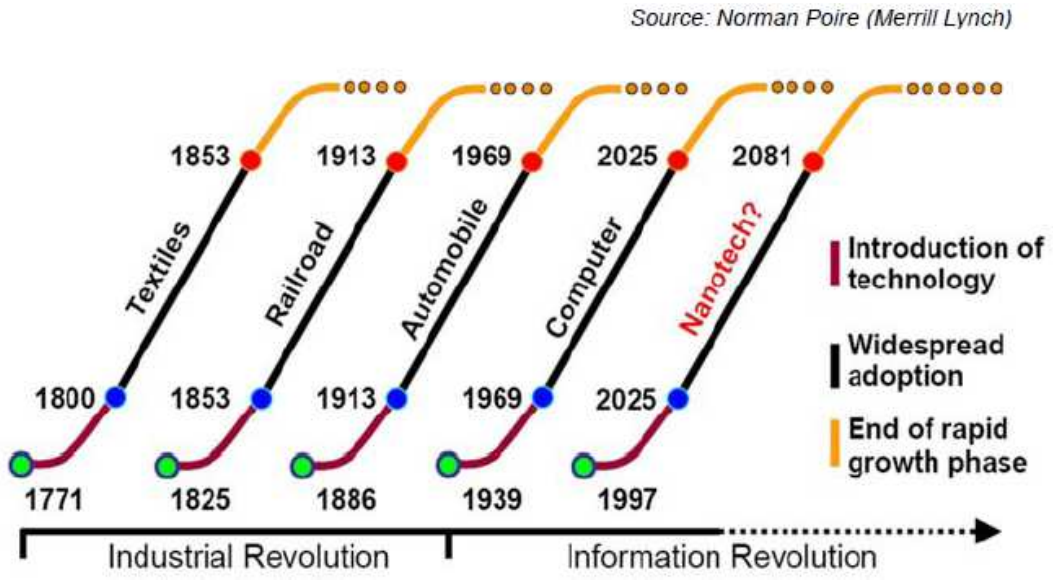

Figure 1.1 Growth of innovations (Poire, N.).

Organizations and companies such as NSF(National Science Foundation), Cientifica and Lux Research Companies searched for marketing, made surveys and predicted that nanotechnology would reach 3 trillion dollars marketing growth in the next 10 years, and would be the industrial revolution of 21st century (Nanobulletin09, 2010).

Ever-increasing demands arise from industry to interest new ideas and nanotechnology based products and to protect intellectual property. In the next decade, diversity of industrially developed nanostructure products and societal effects of nanotechnology are probably going to increase rapidly (Roco, 2003). Nanoscience will be a crucial component for understanding nature more clearly in the future decades. Significant subjects contain great cooperations in interdisciplinary studies, specific education and training, and transferring of opinions and people to industry(Roco and Bainbridge, 2001). Well-equipped workers that have multidisciplinary aspect are main need for rapid progress of new technology; therefore, the new generation should be educated and trained in a short time about nanotechnology, which is the main challenge for progress of nanotechnology. And, that kind of education should be introduced not only in collages but also in the kindergarten level. Due to the similar reasons that microscopic approach has made dominance in the last 50 years, the concepts of nanoscale (atomic, molecular and supramolecular levels) should be introduced in the

education system in the next decade. Additionally, people from scientists to nanotechnological audiences who may contribute to decision making in nanotechnology use and financial support should be informed (Roco, 2003).

One of the most significant scientific and technological progresses in twenty first century has been biotechnology and its applications in various areas (Ozel et al., 2009). Informing the students about scientific and technical aspect of biotechnology and to qualifying them as the future's decision makers to handle with innovations and risks of biotechnology using senseful ways is a responsibility (Harms, 2002). Like Hurd (1994) stated, could be much better forwarded in schools become modern science curriculum and "prepare new minds for a new age" (Hurd, 1994).

The purpose of the current study is to raise awareness of elementary school students and to train them about nanotechnology and biotechnology subjects, and to encourage educators in integrating these subjects to elementary school curriculum.

1.2 WHAT IS NANOTECHNOLOGY?

Indeed, there is not a shared and explicit definition of nanotechnology. However, a general concurrence emerged that nanotechnology can be described as a technology connected to the production, research and application of lateral structures, layers, molecular units, inner boundary layers and surfaces in critical scale or fabrication tolerances that enlarge from about 100 nanometers down to atomic rules to size (Luther, 2004). U.S. National Nanotechnology Initiative (NNI) explains nanotechnology as, "Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers." (Web Page, 8).

Nanotechnology works at the atomic, molecular and supramolecular levels, in the scale of 1 to 100 nm space and this range allows us to generate, manipulate and utilize matters, tools and systems with basically new properties and functions because of their tiny structures. Nanotechnology has the comprehending of the phenomena and processes at the nanoscale and integration of nanostructures through larger lengths. All of the substances and systems form and constitute their foundation at the nanoscale (Roco, 2002). A blood cell is nearly 7.000 nm wide, a water molecule approximately 0.3 nm

cross (Web Page, 11), a single wall nanotube is about 1.2 nm in diameter, molecules of DNA are about 2.5 nm wide; proteins are between 1 and 20 nm, an ATP biochemical motor consisted in living cells is about 10 nm in diameter. By the size of a human cell, a molecular machine like ATP biochemical motor may be minimized. In the same region wide surface space and powerful reactivity are preponderant (Roco, 2002).

1.3 NANOTECHNOLOGY SAMPLES FROM NATURE

As Dumanli and Yurum (2005) pointed out nanomaterials has been existent in nature for millions of years, but people started to recognize beneficial use of nanotechnology just nowadays (Dumanli and Yurum, 2005).

1.3.1 Lotus Leave

Nature uses a couple of different manner to arrange things hydrophobic or hydrophilic. Lotus leaves keep very small, only a few hundred nanometers size hairs. These tiny hairs are hydrophobic and aid to keep up water. Thus, when the collected water gets big enough, its form becomes a drop and rolls down the leaf (Web Page, 3).

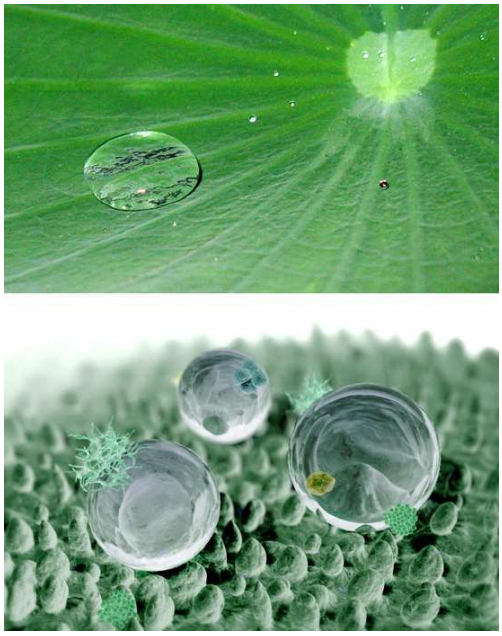

Figure 1.2 Water droplets roll across the leaf surface and pick up dirt particles (Web Page, 16).

1.3.2 Namibia Insect

The Namibia beetle lives in Namibia, a country in Africa. The Namibia beetle has a mechanism to collect water on his back. This mechanism has also very small bumps of hydrophobic instrument that aid with collecting water. The drop of water slides down to the back of the battle when the water drop gets big enough, so that the beetle can drink it (Web Page, 3).

Figure 1.3 Namib insects collect humidity from the air on his back as droplets and they fall down to the insects' mouth (Web Page, 10).

1.3.3 Gecko's Foot

Geckos have very sticky nanometric size width pads that cover their toes. With these sticky nanometer-sized pads, Geckos can easily climb on walls. The pads are sticky enough to allow them to hang upside down, but not too sticky to prevent them from pulling their feet off the surface (Web Page, 3).

Figure1.4 Geckos' sticky nanohaired foot (Web Page, 3).

1.3.4 Butterfly Wings

The surfaces of butterfly wings are made of long and thin parallel hair-like structures that are just 150 nanometers thick and are separated by air spaces. The fibers and air have different refractive effects on light, striking the wings, causing interference and producing bright iridescence (Web Page, 4).

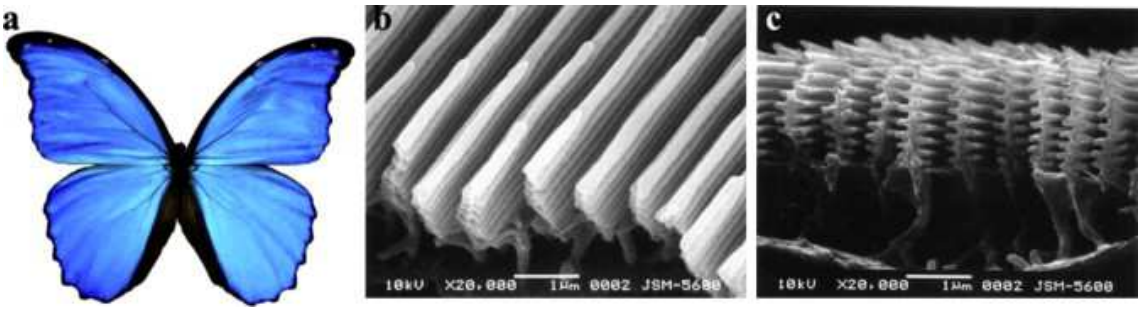

Figure1.5 a) *Morpho Didius* b) Oblique view SEM images c) A croos section of a ground scale of *Morpho Didius* butterfly (Kesong and Jiang, 2011).

1.4 HISTORICAL DEVELOPMENT OF NANOTECHNOLOGY

The opinion of manipulating properties of a chemical initially started with the ancient alchemists. They investigated to get an immortality elixir or “get rich quick” formula manipulating guide into gold knowing that chemical reactions and purifications could make such things occur. Those early alchemists were literally trying to make nanotechnology via manipulating atoms to obtain requested compounds (Williams and Adams, 2007).

Early nanomaterial samples were relied on craftmen’s experimental perception and manipulation of materials. One of the usual stages in their processes was usage of high heat for producing these materials with new properties (Web Page, 1).

4th century: A sample for dichroic glass is The Lycurgus Cup (Rome). The glass contains colloidal gold and silver; thus, provides the opaque green appearance when the light comes from outside. On the other hand, it becomes translucent red when light comes from the inside (Web Page, 1).

9th-17th Century: Glowing, shining “luster” ceramic glazes that included silver, copper, or another metallic nanoparticles was first used in the Islamic area and then in Europe (Web Page, 1).

6th-15th Century: Nanoparticles of gold chloride and other metal oxides and chlorides provided rich colors to stained glass windows of European cathedrals; additionally, gold nanoparticles behaved like photocatalytic air purifiers (Web Page, 1).

13th-18th Century: “Damascus” sword blades involved cementite nanowires and carbon nanotubes, a very high carbon steel formulation that provided them power, resistance, and ability of keeping a sharp edge, and an apparent wavy figure in the steel, which gave blades their name (Web Page, 1).

Examples of Discoveries and Developments Enabling Nanotechnology in Modern Area

1959: Entitled “There is Plenty of Room at the Bottom” lecture was presented by Professor Richard Feynman in 1959 at the annual meeting of the American Physical

Society at the California Institute of Technology. Feynman presented the opinion that it is possible to manipulate and control matters on an ultrasmall scale by forming and operating matter one atom at a time. He explained we could fit in 24 volumes of the encyclopedia Britannica on the head of a pin (Williams and Adams, 2007).

1974: Professor Norio Taniguchi from Tokyo Science University used the term nanotechnology for the first time to explain accuracy machining of materials at the atomic-scale dimensional tolerances (Web Page, 1).

1977: Eric Drexler started the concepts of molecular nanotechnology at MIT (Massachusetts Institute of Technology) (Web Page, 5).

1981: Gerd Binnig and Heinrich Rohrer from Zurich Research Laboratory of IBM invented the scanning tunneling microscope which permits scientists to observe and move each individual atom for the first time. They explored that they could move atoms around into shapes according to their demands by using an electrical area and a particular nanoprobe with an ultrasmall tip (Williams and Adams, 2007). Binnig and Rohrer won the Nobel Prize in physics with their invention of scanning tunneling microscope in 1986 (Web Page, 1).

1985: Rice University researchers Harold Kroto, Sean O'Brien, Robert Curl, and Richard Smalley found out the Buckminsterfullerene (C60), usually known as the buckyball, which is a molecule comprised completely of carbon and looks like a soccer ball in form (Web Page, 1). The novel carbon family was termed the fullerenes (Williams and Adams, 2007). For their contribution in this exploration and that of the fullerene molecules group more generally, the team won the 1996 Nobel Prize in Chemistry (Web Page, 1).

1986: First book about nanotechnology was published by Eric Drexler named as "Engines of Creation: The Coming Era of Nanotechnology" (Web Page, 5), and atomic force microscope was invented by Gerd Binnig, Calvin Quate, and Christoph Gerber (Web Page, 1).

1989: Don Eigler at the IBM Almaden Research Center in San Jose, California shaped the letters of *IBM* by using 35 xenon atoms; and photographed his achievement (Williams and Adams, 2007).

1990s: Early nanotechnology companies started to run, such as Nanophase Technologies in 1989, Helix Energy Solutions Group in 1990, Zyvex in 1997, Nano-Tex in 1998 (in US) (Web Page, 1). Correspondingly, the first journal about nanotechnology was published (Web Page, 5).

1991: Multiwallet carbon nanotubes are discovered by Sumio Iijima (Ak, 2009). CNTs, similar with buckyballs, and their structure completely consist from carbon, but they have a tubular form. Carbon nanotubes demonstrate very unusual properties, like strength, thermal and electrical conductivity (Web Page, 1).

1992: Single wallet nanotubes were invented by Sumio Iijima and Buthene (Ak, 2009).

1993: Nanocrystals (quantum dots) synthesis was operated via a method developed by Moungi Bawendi of MIT. This method allowed for implementations ranging from calculating to biology for highly effected lighting and photovoltaics (Web Page, 1).

1998: DNA-based nanomechanical tool was invented for the first time (Web Page, 5).

1999: An electronic key with a single organic molecule was invented for the first time by M. Reed and J.M. Tour (Ak, 2009).

1999–early 2000's: Nanotechnological products began to appear in the marketplace (Web Page, 1).

2000: In the U.S., President Bill Clinton established the National Nanotechnology Initiative (NNI) (Web Site, 5). The U.S. government founded $422 million for the first time for nanotechnology research (Ak, 2009).

2003: Naomi Halas, Jennifer West, Rebekah Drezek, and Renata Pasqualin at Rice University enhanced gold nanoshells. It provides lots of advantages for breast cancer discovery, diagnosis and treatment without invasive operations, radiation or chemotherapy (Web Page, 1).

2004: Nanoscience and Nanotechnologies: Opportunities and Uncertainties were published by Britain's Royal Society and the Royal Academy of Engineering. This

publication called attention to possible environmental, ethical, health, social and regulatory subjects related with nanotechnology. And first college-level nanotechnology education program was established by SUNY Albany the College of Nanoscale Science and Engineering in the United States (Web Page, 1).

2006: A nanosized car was made by James Tour and colleagues at Rice University. The car consists of four spherical C60 fullerene (buckyball) wheels and oligo (phenylene ethynylene) with alkynyl axles (Web Page, 1).

2007–: Angela Belcher and colleagues at MIT invented a lithium-ion battery with a usual virus type that is harmless to people, to use a cheaper and environmentally benign course (Web Page, 1).

2008: A great milestone through the protein arrangement path to efficient nanosystems and advanced nanotechnology has been accomplished. The design was provided with computational ways of enzymes. The enzymes catalyze reactions without biological enzymes (Web Page, 6).

2009–2010: Nadrian Seeman and colleagues invented various robotic nanoscale assembly tools similar to DNA at New York University (Web Page, 1).

2011: DNA molecular robots learned walking through branched roads in any direction (Web Page, 5).

CHAPTER 2

POTENTIAL RESEARCH AND APPLICATION FIELDS OF NANOTECHNOLOGY

Because of two major reasons the properties of materials can be unusual on nanoscale. First, nanomaterials have larger surface area accordingly the same mass of larger formed materials. Thus, the materials can be more chemically reactive, and affect electrical or strength properties of materials. Second, classical physics laws turn off to quantum effects below 50 nm, thus it promote optical, magnetic and electrical behaviors of materials different from their larger scale forms. These effects can make materials gain very practical physical properties, like extraordinary electrical conduction or resistance, or a high heat storing and transferring capability and can even modify biological properties, with silver for instance occurring a bactericide on nanoscale (OECD and Allianz Report, 2005). All these differences give us opportunities for new applications. Thus, nanotechnology allows for young methods of manufacturing. At the beginning of the twentieth century, for building excessively small circuits and materials, everything must be done with diligent sensitivity and care in super clean rooms (Williams and Adams, 2007).

2.1 APPROACHS OF NANOTECHNOLOGY INDUSTRY

Two main production methods were distinguished about nanotechnology;

2.1.1 Top-Down Approach

Top-down approach means that using particular etching and machining methods like lithography and ultraprecise surface for figuring decreasing microscopic elements

construction sizes to the nanoscale (Luther, 2004). Tiny materials are etched with very sensitive tools, chemicals, and a pattern onto a layered substrate to provide the correct circuitry. Top-down manufacturing explains how computers are manufactured at present (Williams and Adams, 2007).

2.1.2 Bottom-Up Approach

Bottom-up approach means putting together atoms to make greater nanoproducts, thereby producing unique nanotechnological products of the nanoproduction course (Elbadawi, 2010). Self-assembly of microcapsules and other nanoparticles are made with the bottom-up approach. This is also how computer and electronics designers anticipate making very small chips to put in a fingernail or to place under the skin (Williams and Adams, 2007).

2.2 NANOTECHNOLOGY TOOLS

Manipulating atoms and molecules individually was imagined by scientists for a long time. Eventually, scientists can project new materials having specific properties controlling structure on the nanoscale(1-100 nm) phenomenally. Various tools have been improved over the past 20 years, the tools named scanning probe microscopes, allowing not just “seeing” individual atoms and molecules on the surfaces of materials, but they provide opportunity for moving atoms and molecules on the nanoscale at the same time (Web Page, 12).

2.2.1 Electron Microscopes

Various types of electron microscopes were used by scientists for searching the diverse properties of nanomolecules. There are three microscope types that are commonly used; Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) and Analytical Electron Microscope (AEM). To investigate everything at the nanometer scale, these types and different related tools are used based on the sample and the information needed (Williams and Adams, 2007).

2.2.1.1. Scanning Electron Microscope

Scanning Electron Microscopes (SEMs) are utilized to inspect materials topographies via a magnification ground that circumscribes that of optical microscopy and enlarges it to the nanoscale. A SEM can scan a sample surface by a finely focused electron beam for producing an image from the interactions of beam-specimen detected via a large detectors array (Web Page, 14). Generally, 5 to 10 nm or magnifications of 10 to 100,000 SEMs produce high resolutions of a diversity of samples. Besides, some of the current SEMs with a resolution of 1 nm can reach 1,000,000 magnifications (Williams and Adams, 2007).

2.2.1.2. Transmission Electron Microscope

Transmission electron microscopes use very thin (0.5 µm or less) samples lighted up via an electron beam. The electrons pass though the sample with a system of electromagnetic lenses that widen and focus image on a fluorescent screen, photographic film or digital camera and images are recorded by detecting these electrons (Web Page, 15). Although SEMs can only scan a surface of a sample, *transmission electron microscopes* (TEMs) can scan all the way along a sample. A TEM can display images approximately 500,000 times smaller than a human eye and 1000 times smaller than a compound microscope. TEM's resolution is about 0.1 to 0.2 nm (Williams and Adams, 2007).

2.2.1.3. Analytical Electron Microscope

A TEM, which is supplied with analytical tools like X-ray and electron spectrometers, is called an *analytical electron microscope* (AEM). AEMs can measure and shape images from the X-rays produced by atoms when they are bombarded via many electrons. Additionally, when they move through materials, AEMs can measure the electrons' energy loss.

Extremely high performance of AEMs allows for too much (up to 0.1 nm) high resolution imaging qualifications to scientists. Biochemical research, smart coating, fuel cell research, magnetic nanostructures and semiconductor quantum dots are principal areas that take advantage of AEM scanning (Williams and Adams, 2007).

2.2.2. Scanning Probe Microscopes

Scanning probe microscopes (SPMs) are a group of tools used to examine the surface types of materials from atomic scale to nanoscale (Williams and Adams, 2007).

2.2.2.1. Scanning Tunneling Microscope

Depending on the type of STM probe tip, different kinds of images can be seen. The tip is kept at a stable distance such as one atomic diameter or 0.2 nm away, and the tip is increased or decreased to keep the current flowing at a stable value, which means the distance is continued. Generally, a voltage is produced between the surface of the conductive sample and the probe tip; and this voltage can cause a flow of electrons across the gap, which is termed as tunneling (Williams and Adams, 2007).

2.2.2.2. Atomic Force Microscope

The atomic force microscopes (AFM) use a laser reflecting off the behind of the probe tip to determine the position of the probe tip mounted on an elastic beam. The probe tip goes up and down as the tip moves along the surface because of the valleys and ridges on the surface of the sample. The AFM has two resolution measures: the measurement plane and the vertical direction to the plane. Highermost AFM tip is an ultra sharp carbon nanotube tip, which is able to chase outline of a sample much correctly (Williams and Adams, 2007).

2.2.2.3 Laser Scanning Confocal Microscope

For sweeping through a sample, a laser scanning confocal microscope (LSM) utilizes scanning mirrors and a laser light (ultraviolet). All the things that you can view to one focused slice are limited by a small aperture. A computer composes numerous single slice images, thus 3-D picture comes into existence on a monitor (Williams and Adams, 2007).

2.3 RESEARCH AND APPLICATION FIELDS OF NANOTECHNOLOGY

Expected developments in nanoscience and nanotechnology carry out “big business” potential obviously. Planned global market indorsements of over than $1 trillion each

year are anticipated in the fields of fabricating electronics, health protection, pharmacy, chemical plants, transportation and environment permanency over the future 10 to 15 years (Sweeny, 2003).

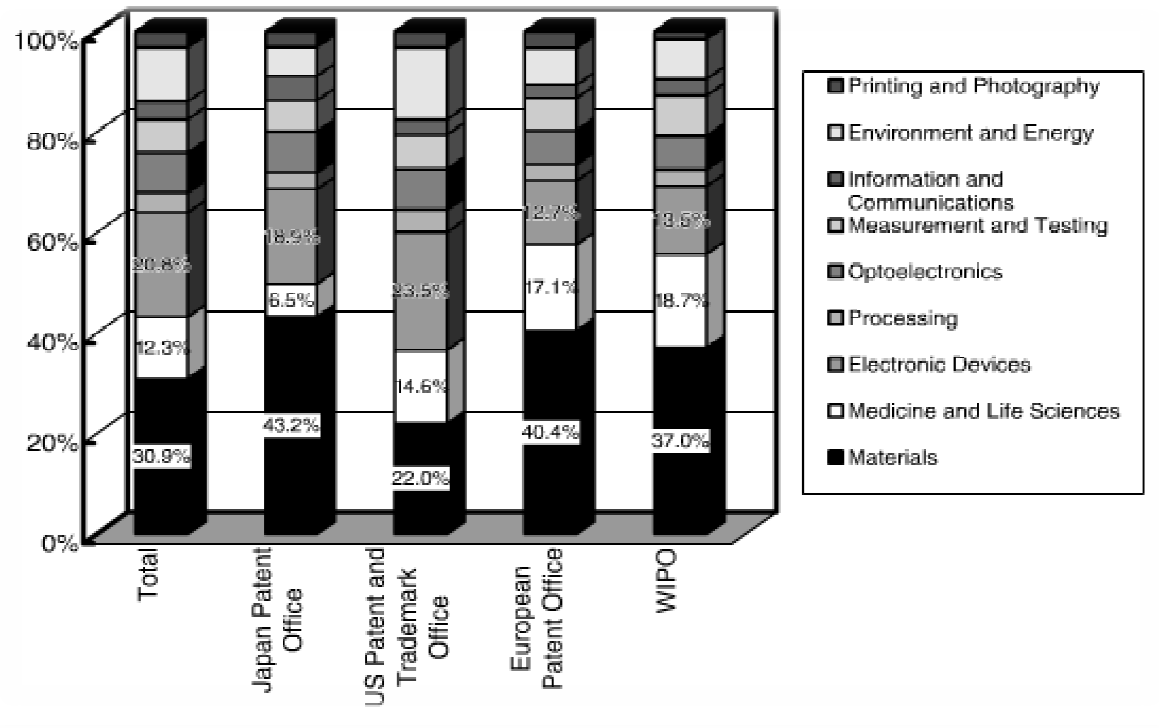

Figure 2.1 Nanotechnology patent applications percentage by nine designated technology areas (Daisuke, 2006).

As it is shown in figure materials, electronic devices and then medicine and life sciences areas are most patented nanotechnology applications. Several nanotechnology based applications and elements are explicated below in short.

2.3.1 Information and Communication

It is forecasted that this new area would be very important for especially communication and information technologies (Luther, 2004).

Displays: Several nanotechnological flat-panel display technologies seem promising for the future; for instance, organic light emitting diodes (OLED) or carbon nanotube based field emission displays (CNT-FED). And two of them have so much anticipated marketing potential, if substantial technological problems can be solved (TUSIAD, 2008).

Data Processing and Storage: Nanotechnology creates the possibility for development of very high integrated logics, immensely high storage intensity in tiny mass memories and top performance of non-volatile working memories for hardware systems (Luther, 2004).

Mobile electronics: In the range of thermoelectric converters, batteries, miniature fuel cells, or solar cells, nanotechnology can considerably develop mobile energy fabrication. Mobile electronics applications will include wearable electronics woven with textile fibres for health surveillance or telecommunication goals. Additionally, increased or virtual reality tools in the work place or for amusement as good as versatile handheld tools with multiple uses as a personal waiting-man, synchronical translator, and mobile library e.g. expected to be realized in the future (TUSIAD, 2008).

2.3.2 Medicine and Health Care

Engineering materials on nanoscale permits for new medical therapies like producing nanoparticle-based drugs that have advanced specificity for target cell and as a result diminished the side effects (Pautler and Brenner, 2010). Atomic force microscope (AFM) technology is used to develop smaller and better sensitive microarrays for utilizing in diagnostics and drug exploration. For example, AFMs can be used for surfaces which have nanostructure, and it can make these surfaces much more biocompatible (Roco and Bainbridge, 2001).

Many drugs are not marketed because they are not water soluble adequately. Formulating drugs by using nanoparticles can also alter drugs' solubility; enhance their

endurance against enzymes and stomach acid to permit much better uptake from the small intestine and to allow manipulated release (for example, over days instead of minutes and hours). Nanotubes associate with different mechanism for drug transportation both as a “container” and possibly a system for “nano-injection” inside cells. Many nanotechnology based drugs like Doxil for ovarian cancer and Abraxane for breast cancer is being used for cancer treatment at present, and these nanotechnology based drugs have been approved by the FDA. Additionally, progression in regenerative medicine using nanofibers and carbon nanotubes, nanodesigned extracellular matrices and dendric nanopolymers are some instances of young technologies that are being improved to effect different main causes of fatality and sickness rate in the USA including cancer, Alzheimer’s and heart disease (Pautler and Brenner, 2010).

Nanotechnology will provide us very quickly sequence of an individual DNA with nanosequencing and consequently decide genetic sensibility to disease, medicine intolerances and medicine metabolism progressions at long last. Diseases will be detected more quickly via progress in lab-on-a-cip tools, and individual biotic signs could be screened with more detailed with similar tools (Luther, 2004).

Of specific importance is the US National Science Foundation’ emphasis on the parallel research of appearing ethical and social matters emerged with rapid growth in nanoscience or nanotechnology. The convergence of nanotechnology, biotechnology, information technology and cognitive science may emerge novel scientific methodologies, engineering examples and industrial products that would increase human mental and conversational talents. Science would be ready to accomplish in a very quick program to figure out the structure and activities of the human mind and the Human Cognome Project by combining these disciplines (Sweeny, 2003).

Other progresses are being created in medical tools and materials to use in surgical procedures that are fewer invader, guiding to shorter recovery periods and diminished hazard of postoperative infections or different challenges. These kind of innovations will increase the quality of life; may decrease the entire cost of health care and enlarge expectancies of life (Pautler and Brenner, 2010).

2.3.3 Chemistry

Nanotechnological fabrication and chemical-based nanostructured materials have already begun in the chemical industry. Some chemical nanotechnology based products are in the market for a while and in the long term, nanotechnology based chemistry is predicted to go further to develop beyond traditional materials. For instance, self cleaning ceramics and paintings (lotus-effect), nanoparticle related sunscreens, biochips working with nanoparticle markers, loader in car wheel or catalysts (TUSIAD, 2008).

Developed countries are targeting to exchange metallic and semiconducting elements with carbon based materials as tag after replacement policy. For example, organic semiconductor, involving carbon nanotubes, are investigated as potential substitutes for semiconductor elements like selenium, germanium, cadmium, arsenic, gallium and antimony, of which China is the principal supplier for many. Additionally, due to their unusual electric and thermic properties, carbon nanotubes are hoped as an alternative for high-conductive metals in electronics, like silver, gold and copper (Schummer, 2007).

Generating “intelligent” materials with inborn sensing and behaving properties, adjustable optical, mechanical and thermal properties or even properties healable by their own are some of the future aims of molecular nanotechnology. One purpose here is to copy of biological processes for technological practices by combination of biological and artificial materials, buildings and systems. This nanobiotechnology area is still in the condition of essential research at present, but it is considered one of the most promising research areas for future (Luther, 2004).

2.3.4 Food Sector

Nanotechnology can bring lots of potential advantages to the food industry (Duncan, 2011). Lots of vitamins and their heralds like cerotinoids are not soluble in water. But, when smartly produced and developed as nanoparticles, lots of vitamins and their precursors can quickly be combined with cold water; thus, their biological effectiveness increases in human body. All around the world market, potential of such micronized materials predicted at 1 billion dollars (Luther, 2004).

Nanocompound plastics could procure the basis for powerful packages which have high bar to oxygen and water vapor. Nanoparticles that are silver and metal oxide are strong antimicrobial actors which can put away foodborne pathogens; and nanosensors suggest new methods to identify microbes, gases or chemical waste in complicated food matrices. And nanoencapsulation can aid strengthen staple foods with fundamental nutrients (Duncan, 2011).

2.3.5 Energy and Environment

Nanotechnology has a very big potential for all of the parts of energy sector such as fabrication, storage, distribution and use of energy supply of the world. Engineering solar cells including nanorods or nanolayers might importantly raise the electricity amount which is transformed from sun light by utilizing as more efficient light absorbers nanostructured surfaces and nano porous electrodes (Luther, 2004).

Nanotechnology applications for storing the energy involve producing batteries and fuel cells by utilizing nanoparticles and nanotubes. Currently patented lithium ion batteries that contain nanosized lithium titanate can procure 10-100 times better charging or discharging degree compared to widespread batteries. A number of groups are studying hydrogen storage probability in nanostructured materials like, carbon nanotubes, nanocrystalline magnesium compounds or organometalic compounds, and they might be used for the sector of fuel cell (TUSIAD, 2008).

Metals can become lighter, harder and stronger; and ceramics can become more shapeable and flexible by using nanoparticles. Thus, same materials can decrease fuel, energy and materials (Luther, 2004). For environmental cleanliness, the organization and alteration of atomic and molecular scale matters present a lot of possibilities. Unusual properties of current nanosize materials can make the most advantageous in cleaner energy creation, energy capability, treatment of water, and environmental remediation (Williams and Adams, 2007).

Globally water distillation and desalinization are some of the significant areas of environmental security and preventative defense since they can supply the water necessity in the future (Roco and Bainbridge, 2001). Without question micro- and nanopourus filter production can help the cleaning of the microbes and other pollutants

from water (Schummer, 2007). Nanotechnology based water desalinization tools have been architectured desalt sea water spending minimal 10 times less energy than state of the art reverse osmosis and minimum 100 times less energy than distillation (Roco and Bainbridge, 2001). Thus, new water sources can be found thanks to these desalination plants (Schummer, 2007). Nanodesigned ceramic membranes could be stated in alignment within traditional treatment systems for final cleaning of contamined air and water (Williams and Adams, 2007).

2.3.6 Textile

Nanotechnology has already affected textile industry, and research that involves nanotechnology to develop performances or generating unique functions of textile tools are amazing. These processes finish set up an immense level about textile performance including stain-proof, hydrophilic, anti-static, shrink-resistant and wrinkle-proof qualification. Also, if they are worn close to the body, these clothes can transform courted mechanical pressure into electrical indicator and can provide the monitoring of somatic functions like pulse and heart beat. Manufacturing clever, sensible textiles with immense qualifications and increasing, healing current functions, productivity of textile tools are two main important things for the future progress of nanotechnology based textile. This new qualifications in textile technology to be developed contain;

-Wearable energy depot and solar cell,
-Knowledge acquisition convection and sensors,
-Civilized, multiunit conservation and detection,
-Medical-care and wound treating functions,
-Self-cleaning and mending functions.

Textile is going to have a very important role in future material market; thus, it is expected that nanotechnology will provide about hundreds of billions dollars effect on novel materials within a decade (Qian and Hinestroza, 2004).

2.3.7 Space Exploration

Nanobuilding is important to the engineering and producing of high-resisting, thermally stable, lightweight materials for rockets, aircrafts, space stations and planetary

or solar discovery platforms. The increased necessity of minimized, greatly automated systems will guide influential developments in producing technology also. Furthermore, improvement of nanostructures and nanosize systems that can not be produced on Earth may help by force of the low-gravity and high-vacuum space environment (Roco and Bainbridge, 2001).

2.3.8 National Security

Particularly in national security applications of nanotechnology will create a power that provides very big advantages and immortal effects. For national defenses and security, nanotechnology applications and usage are determined in many fields. Some of these are like follows,

-Miniaturized sensors, high speed processors and communication devices,
-Cyber artificial systems for education,
-Unmanned land, sea, air drives,
-High performance in military platforms,
-Developed chemical, biological, nuclear sensation systems and care drives,
-Developed systems for observations and blocking of nuclear fall out,
-Enhancing human power performance,
-Creating systems which provide brain-machine sublayer (Ozer, 2008).

2.4 POTENTIAL RISKS AND BENEFITS OF NANOTECHNOLOGY

According to some, declared as starting in a new age-the “next industrial revolution” nanotechnology is the latest in a long line of technologies (Hansen, 2009). Currently 1317 nanoproducts are offered for sale, and the number of these nanotechnology products increased 521% from March 2006 to March 2011. Health and fitness category have 738 products, and it is the largest main category. This category has like cosmetics and sunscreens products (Web Page, 2). As it is shown in the diagram the number of nanotechnological products fastly increasing year by year;

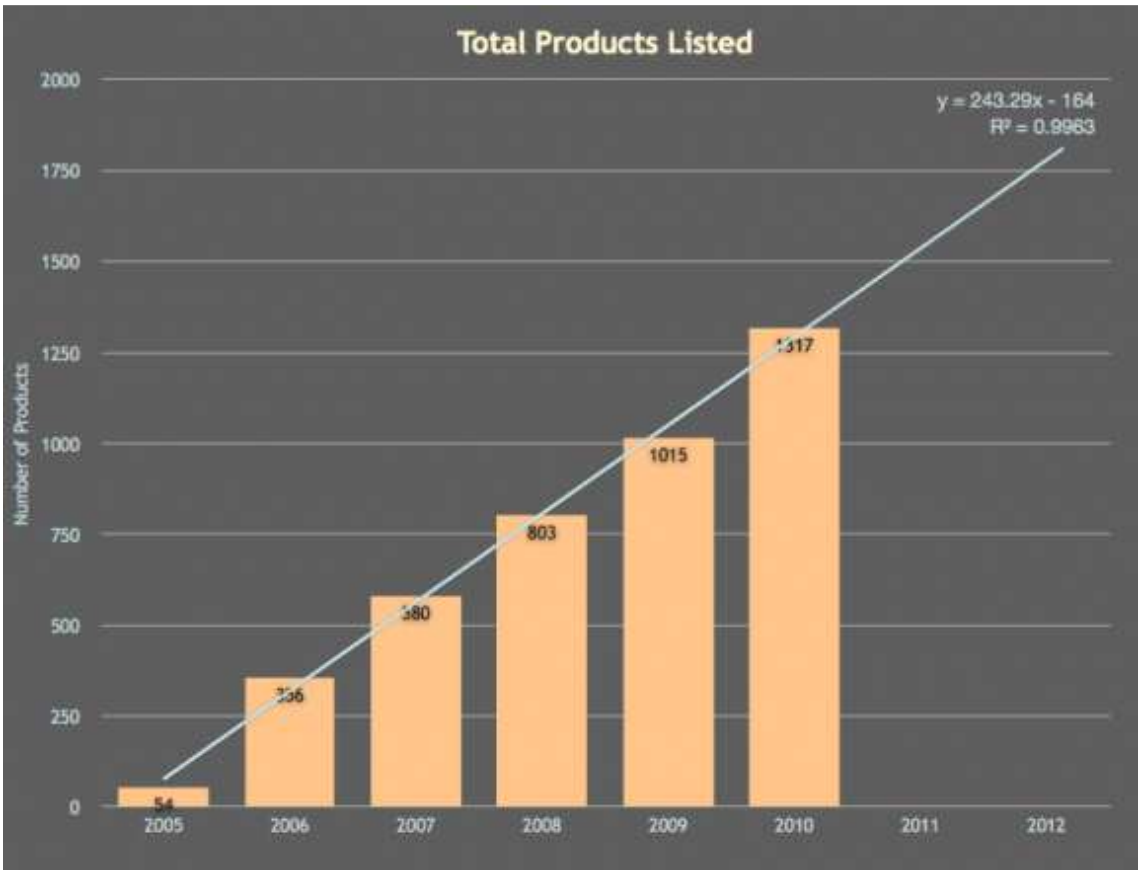

Figure 2.2 The number of nanotechnological products reported annually in the consumer products inventory (Web Page, 2).

Besides the positive expectations, there are important concerns too; big proportion of probable environment, health and safety risks (EHS) of engineered materials and nanomanufacturing process are not clear (Ok, 2012).

2.4.1 Future Promises of Nanotechnology

With their interfacial layers, quantum energetics, small measurements combined with extraordinary optical and electronic properties, it is assumed that nanomaterials would be stage breaking development in scientific fields such as pharmaceutics, knowledge archiving, chemical and optical computers, metals, ceramics, polymers, catalysts, sensors, batteries etc. In addition to their chemical, mechanical or structural

actions, technologically functional properties of nanomaterials attract many researchers' interest (Dumanli and Yurum, 2005).

Increasing technological novelties related to nanoscience are likely to be marketable as they allow for bigger control over every atom and every molecule building (Sweeny, 2003). Instances of these innovations are expected to appear in a large variety of fields like following:

- With the help of nanobots regenerating the stratospheric ozone layer.
- Establishing methods in nanosurgery, fixing damaged DNA.
- Establishing molecular circle boards, improving molecular computers, developing the data storage.
- Copying precious products like food and diamonds; using new applications of carbon nanotubes, enhancing the quality and stability of metals and plastics; producing ”smart” materials like, biomimetics, ”shape memory” composites (Sweeny, 2003).

Nanotechnology is expected to bring immense benefits in electronics, medicine, energy, consumer products and different applications, and it is predicted that nanotechnology will have 3.1 trillion dollars amounts of products by 2015 (Ok, 2012). In the future 10 to 20 years; advancing technologies will amaze us (Williams and Adams, 2007).

2.4.2 Potential Risks of Nanotechnology

The trueness of nanotechnology is progressing in ways that serve us all things from quicker and smaller computers, better tennis balls, and stain-repellent clothing, to transparent sunscreens (SPF60), molecular sensors, and cell-characteristic cancer treatments. Currently, hundreds of nanotechnology based brands are on the market (Williams and Adams, 2007). Maynard (2006) related these products the tip of nanotechnology practices iceberg because lots of researchers and nanotechnology industry employee are creating and engineering nanomaterials continuously. And we have a few information evaluating and leading risks. Because it will come with the potential to present benefits and risks to people and environment health at the same time, we can not assume that nanotechnology will be different from other industrial innovations certainly (Maynard, 2006b). Holsapple M. et al. (2005) stated that environmental and other security worries related to nanotechnology have already

increased. Because of their high persistence, the wide surface area and the related raised reactivity of some nanoparticles can enable wide transport in the environment or they can affect biological organizations from communications with cellular material (Holsapple et al., 2005).

In the recent times, particularly following some studies that declared that a number of nanomaterials can conduce to negative result of laboratory animals, benefits and potential hazards of some nanoproducts have been argued (Hansen, 2009). Number of researches and experiments has been done on respiration and dermal exposure to nanoparticles and different ultrafine particles (Holsapple et al., 2005). There is some data about a number of nanoparticles may be able to move from the lungs into the bloodstream (Maynard, 2006b) and nanosized particles aggregate in the inhalation tract by diffusion mostly(Hansen, 2009). There is very little information about the disposition and destiny of the nanosized particles (<100 nm) in the body. Toxicologists require understanding the exposure and impacts of discrete nanosized particles for precisely understanding nanomaterials (Hansen, 2009).

Fibre-shaped nanomaterials can cause unusual inhalation damage, and their pulmonary toxicity should be utilized as an emergency matter. Respiteing of enough dose of asbestos fibres can start to the malignant patience mesothelioma. There is no enough information about fibre-shaped nanosized particles consisting from carbon and other materials will act like asbestos or not (Maynard, 2006a).

Nanomaterials might impact other spices, probably changing ecological balances even if they are not harmful to humans. For example, researchers are worried that silver nanoparticles that use an antimicrobial agent can be a potential hazard to beneficial bacteria in the environment. Matters adding the bottom of the food chain have a habit of impressing organisms higher up the chain, thus affecting humans (Maynard, 2006b).

In recent years lots of researchers and scientists who were interested in nanotechnology, international organizations and regulatory agencies have played an active role against advancing risk evaluation for nanomaterials. As well as industry, regulatory agencies, academics and scientists in government all of them have a part in these improvements, for instance under chemicals lawmaking with regard to

nanomaterials(e.g. Registration, Evaluation, Authorization and Restriction of Chemical substances, REACH) (Khara et al., 2010).

Exposure evaluation is prevented by difficulties in monitoring nanosized material exposure in the work field and the environment, by the fact that nanosized materials environmental and biological pathways, are still largely unexplained (Hansen, 2009). Maynard (2006) argued that in the future 10 years possible effects of developed nanomaterials on the people's health and environment could be predicted. People generating and using nanomaterials could improve unexpected diseases increasing from their exposure without targeted and strategic risk investigation. Civil reliability of nanotechnologies could be decreased along true or expectable dangers and sue fears may make nanotechnologies less interesting for financier and the security industry. If strategic investigation is promoting sustainable nanotechnologies, in which potential hazards are minimized and advantages maximized, the science society requires to move at present (Maynard, 2006a).

CHAPTER 3

NANOTECHNOLOGY CONSTRUCTIONS ALL AROUND THE WORLD

Japan (approx. $800 million in 2003), USA (approx. $774 million in 2003), and Western Europe (approx. $650 million in 2003) have been the leading nations in terms of funding support for nanotechnology. Other developed countries, especially the nations of Southeast Asia (Taiwan, Singapore, South Korea, China), have also raised the funds they provide for nanotechnology investigations (Luther, 2004).

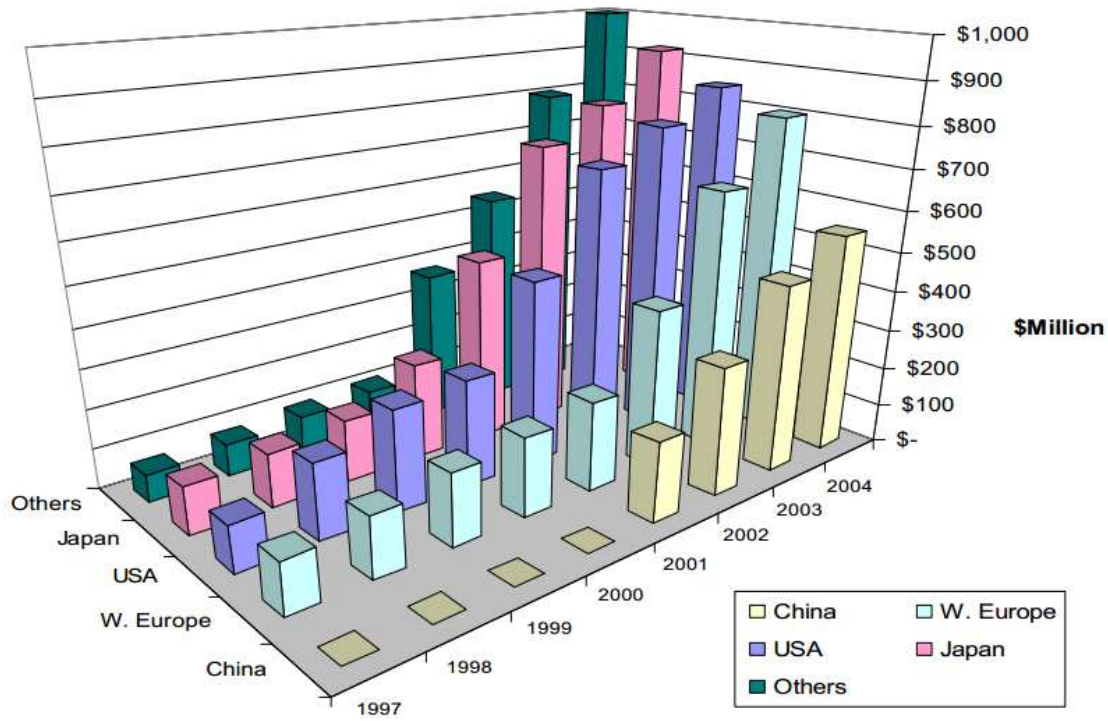

Figure 3.1 Governments nanotechnology funding from 1997 to 2004 (Web Page, 13).

The figure shows Japan followed by the USA is the leader government about making investing in nanotechnology and government's nanotechnology funds are increasing continuously.

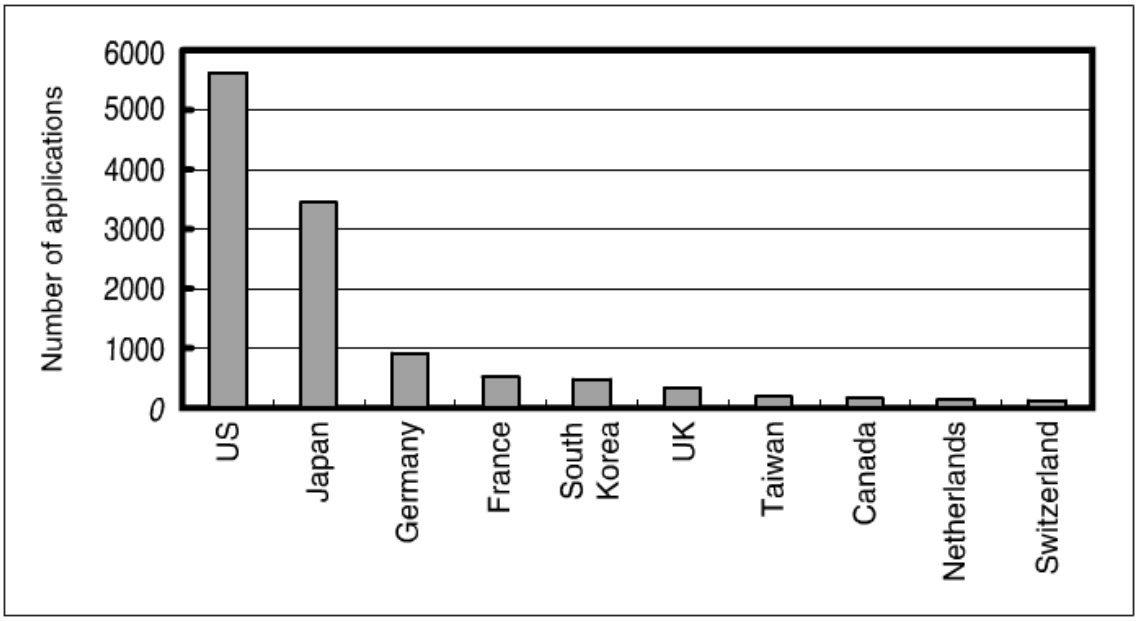

Figure 3.2 Nanotechnology patent application number considering applicant nationality and submitted by four largest patent organizations (Daisuke, 2006).

3.1 UNITED STATES

The US plays a leading role in nanotechnology. United States visioned the importance of studies on nanotechnology early on. A breakthrough in the United States was the establishment of the Foresight Institute by Eric Drexler to raise society's awareness about the future of advanced technologies. The Foresight Institute held conferences on molecular nanotechnology, produced farsighted articles and newsletters, and maintained virtual discussion forums in 1989(Luther, 2004). US economists advocated the significance of nanotechnology; accordingly, Clinton administration promoted nanotechnology as a priority and nanotechnology became one of the most supported programs in the US. As a result, big research centers and university-

company-community collaborations were established (TUBITAK, 2004a). In 2000, Nanotechnology Initiative (NNI) was founded to promote nanotechnology as a national priority. About 100 research centers for nanotechnology were built in almost all large technology universities. Additionally, numerous US corporations such as IBM, Hewlett-Packard, and Motorola, established their own research centers, some of which have collaborations with universities (Luther, 2004).

In the US, nanoscience and nanotechnology research budgets reserved for public agencies (e.g., NSF, DoD, DoE, NIH, NASA, NIST, DoA, DoT, DoJ) were only $270 million in 2000, $467 million in 2001, $604 million in 2002, $710 million in 2003, and more than $3 billion in 2004 (TUBITAK, 2004a). Today, US comes second, after Japan, in terms of publicly funded research. Of the funds, the largest share goes to the National Science Foundation (NSF) and seven ministries, such as Ministry of Defense and Ministry of Energy, with nanotechnology budgets of their own (Luther, 2004).

3.2 JAPAN

Japan has the first position in the world in terms of the public funds allocated for nanotechnology. Japan also has the leading position in nanotechnology development in Asia. It has set up various theoretical and applied nanotechnology research programs. The Nanotechnology Research Institute (NRI) of the National Institute Advanced Industrial Science and Technology (AIST), Institute for Physical and Chemical Research (RIKEN), and Joint Research Center for Atom Technology (JRCAT) are among the most important institutions that conduct research on nanotechnology. Moreover, some business consortiums carry on nanotechnology research, particularly in the field of nanoelectronics (Luther, 2004).

3.3 EUROPE

In the 5th framework program of the European Union, €50 million were designated to nanotechnology research projects under various programmes (e.g., IST, GROWTH and QoL). Concerned with the nanotechnology developments in Japan and the US, the European Union declared nanoscience and nanotechnology as a priority in the 6th

Framework Program and allocated 1.3 billion Euros to support research in this field. Still this amount was only a small portion of the European Union countries' national budgets (TUBITAK, 2004a). Lots of European countries, such as Germany, France, United Kingdom, the Netherlands, Spain, Sweden, and Switzerland, have set up private research programmes in nanotechnology (Luther, 2004).

3.4 UNITED KINGDOM

National Initiative on Nanotechnology (NION) was established by the Department of Trade and Industry (DTI) in as early as 1986. The aim of the NION was to raise an early awareness of nanotechnology. A Nanotechnology Strategy Committee (NSC) was set up to inform the government about nanotechnology. Organization of three technology transfer centers was among the achievements of the NION (Luther, 2004). England granted 45 million sterling from 2003 to 2009 for nanotechnology research and development studies (Nanobulletin08, 2009).

3.5 SOUTH KOREA

Korea strives for becoming one of the top ten countries in the field of nanotechnology in the world. The Ministry of Science and Technology (MOST) supports this target with its 2001-2010 national nanotechnology program. MOST, some other government agencies, and the private sector together allocated ten-year budget of $1.1B for work in nanotechnology. Among significant goals are to improve Korea's nanotechnology infrastructure and build a National Nanofabrication Center at the Korea Advanced Institute of Science and Technology. Also Samsung and LG Electronics have announced important nanotechnology programs, and numerous little firms are focusing on nanotechnology (Luther, 2004).

3.6 CHINA

In 2001 the five-year Chinese NNI started. After the U.S. and Japan, and before Germany, China had the third largest number of publications in nanotechnology for the ten year from 1991 to 2001. In China 956 nanotechnology patents were exported

between 1985 and 2001. About 9% of the world's total nanomaterials patents, 3% of nanobiotechnology patents, and 1% of nano electronics patents were taken by China.

China's government is investing 250 million Yuan (approximately US$30M) for a National Nano Science Center in Zhongguancun, Beijing. The center will promote a technological field for nanotechnology efforts of the nation and will be supported by the Chinese Academy of Sciences (CAS), Tsinghua University, and Peking University. China maintains an attractive market for foreign enterprise, and China will potentially become a leader as the nanotechnology products, mainly nanomaterials, supplier in the future (Luther, 2004).

3.7 OTHERS

In addition to the countries mentioned above many countries possess their national nanotechnology plan and funding programs. For instance, in Switzerland there are strong nanotechnology activities like, "TOP Nano 21" (2000-2003), a nanotechnology investigation initiative targeting the effective transfer of technological innovation into marketable products and promoting mutual projects of universities and industrial partners. Nanotechnology has potential as a strategic technology for novelty and economic welfare in the 21 century, and governments in the world have noticed this. Nanotechnology is developing in an environment where international interactions in science, education, and industrial R&D accelerate (Luther, 2004).

3.8 DEVELOPMENT OF NANOTECHNOLOGY IN TURKEY

Since 1989 Bilkent University Physics Department has been doing intense research in electron transport in low sized quantum structures, scanning tunneling microscope (STM), and atomic force microscope (AFM), edge-surface interactions, nanotribology, nanotube and atom chains. Additionally, Turkey caught Ga-As technology which uses properties of two dimensions electron systems on time and established Advanced Researches Laboratory supported by the Republic of Turkey Defense Industry Undersecretariat. Currently in this laboratory it has made very important optoelectronic

and electronic tools and has developed new technologies with AFM and STM based microscopes (Web Page, 7).

"NanoManyetik Scientific Engines" was established in 1999 as the first nanotechnology company in Turkey, specializing in producing low and high temperature scanning probe microscopes that can work under a wide range of heat like 30mK-300K. NANOVAK, which conducts nanotechnology R&D activity, was established in Ankara. NANOVAK produces "nanovacuum systems" that atomize the matter for nanotechnological products and exports these systems to various parts of the world (Nanobulletin09, 2010). At the end of 2005 State Planning Organization granted 11 millions TL for the establishment of National Nanotechnology Research Center (UNAM) (Web Page, 7). Total amount of this center is 30 million TL and UNAM will sustain its R&D studies in 4000 meter square field laboratories (Nanobulletin08, 2009). By giving substantial importance on training and education Nanotechnology Research Center at Bilkent University is aimed to exploration on experimental and theoretical nanotechnology and nanoscience. The center is targeted theoretical study like the core problems of nanoscience and practice of nanotechnology in nanotubes form, quantum dots, nanowires, anti-friction surfaces and magnetic molecules at the same time as interest fields (Dumanli and Yurum, 2005).

In Turkey, some nanotechnological products are produced and marketed by some companies. NNT Company is developing products which contain boron by using nanotechnology. The company is producing MCDP boron crystallites and injects them to the motor oil. Their products extend oil life in motors in proportion of %100 and reduce carbon emission in proportion to %15 and provide fuel savings selling in Turkey and England. A dye company generated another significant brand, "DYO-Nano". Household furniture company "İstikbal" and its subsidiary company "Boyteks Textile" has improved a nanotechnological fabric named "Biocare" and it prevents ionized radiation spread form such as microwave owen, television, mobile phones electronic tools in proportion to %98,5 (Nanobulletin08, 2009). "Arcelik Company" which is a white good and electronics company, has produced two products; first one is for the hygienic refrigerator and oduor filtering, and the second one is to complete sheltering triangle super hygienic refrigerator. Yesim Textile Company is producing stain resistant, quickly drying and ironing nanofabrics (Dumanli and Yurum, 2005). Damat Tween produced dirt

and waterproof “magic” white shirts, and Elvin Textile developed smart nanotechnological curtains (Nanobulletin08, 2009).

Turkey’s nanoscience and nanotechnology plans for future have been predicted and made decisions via the Scientific and Technological Research Council of Turkey (TUBITAK) which notifies the targets and objectives till the year 2023 (Dumanli and Yurum, 2005). According to Tubitak Vision 2023 Report, nanotechnology is the third of the eight strategic technologies (TUBITAK, 2004b). In Nanoscience and Nanotechnology Strategies Vision 2023 Report TUBITAK determined the nanotechnology subjects of first priority as follows:

-Nanophotonics-Nanoelectronics-Nanomagnetism
-Nanomaterials
- Fuel Cells and Energy
- Nanocharacterization
-Nanofabrication
- Nanosized quantum information processing
-Nanobiotechnology

In the vision 2023 report TUBITAK suggested the following science and technology politics for nanotechnology development;

1) Immediately, interdisciplinary master and doctoral programs should be opened in universities and students which study these programs should be funded by government. Government should provide needed support for post doctoral researches too. Thus, lack of qualified members should be supplied.

2) Universities’ small, medium and big sized industries’ research infrastructure should be built up and developed, and became common with legal arrangements.

3) There should be increasement count of research centers and they should become more common. The surveys which are conducted or guided by industry should be promoted and supported.

4) Developing and extending of technoparks are especially important for advancing nanotechnologies (TUBITAK, 2004a).

Into the next 10-15 years amazing outputs and new markets have been emerged by nanotechnology. It is clearly seen that there have been hundreds of nanotechnology research centers and departments in universities established in Europe, USA and Japan. And in there expert staffs are producing information and technology for national and commercial benefits in a big race. The gap between developed and undeveloped countries will be increased as intolerable and exponentially with nanotechnology. In this sense, nanotechnology is becoming the last chance for economic and scientific development and prosperity in Turkey which could not catched industrial and microelectronics-informatics revolution on time. Gaining this chance will be merely possible; if the expert stuff is powered in national size, and if the educating and promoting technological knowledge will be transferred from generation to generation (TUBITAK, 2004a).

CHAPTER 4

NANOTECHNOLOGY EDUCATION

4.1 NANOTECHNOLOGY EDUCATION IN TURKEY

Many universities like Bilkent, Bogazici, METU, Hacettepe, Marmara, Gazi, Anadolu University, Gebze High Technology Institute have nanotechnology master programmes in Turkey. And lots of universities are working to remove laboratory, supplement and lecturer deficiency for practicing nanotechnological research and education (Nanobulletin08, 2009). In addition to master education, Doga College has opened Yakacik Doga College Nanotechnology Laboratory to introduce their students to nanotechnology, which is the technology of future and developing biomaterials. This laboratory is the first laboratory which is established within a high school. And Doga College is conducting EU projects for integrating nanotechnology in curricula (Web Page, 17).

In Turkey, majority of nanotechnology explorations have been theoretical studies of individuals. On the other hand, the nanotechnology surveys are beginning to rebuild and gain different aspects with 6th Framework of European Union. Turkey has participated to the 6th Frame Programme of European Union and the programme proposals relevant to nanoscience and nanotechnology have already being advocated by the Programme. The first nanotechnology conference was organized by Bilkent University in Ankara in 2005. Under this frame National Nanotechnology Research Center (UNAM) was built by the supplement of Turkish State Planning Organization and Bilkent University (Dumanli and Yurum, 2005).

Besides National Nanotechnology Research Center in Bilkent University (UNAM), some universities are also establishing their own nanotechnology research

centers: For example, in Istanbul Technical University with the partnership of Turkish State Planning and Organization and Physical Engineering Department, Nanoscience and Nanotechnology Advanced Research Institution will be finished in 3 years (Nanobulten08, 2009).

Nanotechnology studies are not a new field for the old state universities such as Middle East Technical University (METU) and Hacettepe University in Ankara and Bosporus University in Istanbul. METU has a Central Laboratory and R&D Center in which the nanotechnology study is focused on smart materials, biomaterials, and Nanocomposites primarily. Hacettepe University has been promoting the area of nanocomposites, nanopolymers and nanobiomaterials with its Departments of Chemistry and Chemical Engineering by active survey groups for years. Nanotechnology and Smart Materials Advanced Technologies Research and Development Center of Bosporus University are promoting in nanotechnology and nanoscience area internationally. Koc University has Micro-Nano Technologies Research Centers. Sabanci University is one of the leader universities in the field of nanotechnology. Nanotechnology researches are conducted researches setting collaboration between different departments such as departments of chemistry, materials science and engineering, bioengineering, and microelectronic engineering there (Dumanli and Yurum, 2005). Fatih Univesity has Bio-Nano Technology R&D Center and the center has 13 laboratories (Web Page, 9). There are also greatly productive high technology institutes in the nanotechnology research field such as Gebze Institute of Technology, Izmir Institute of Technology, and MAM – Marmara Research Center (Dumanli and Yurum, 2005).

Studies which conducted in Turkey have just become university level but giving importance on these subjects in elementary and high school levels such as aboard is an urgent necessity. Turkish children and young people, who will build the future of our country, should know the basic information and research subjects of nanotechnology. And they should enhance a positive attitude about it; naturally it will accelerate studies of universities and nanotechnology producing of industry in our country. A qualified nanotechnology education, which would be given in elementary and high school level, will surely effect the development of students' academic self and future choice of their profession. There should be nanotechnology education departments established in vocational educational institutions, particularly. If universities and industries provide

enough education to workforce of society about nanotechnology, they will sustain their nanotechnology development. If it is too late to provide this education, there will be an unaware generation about technology of the future. Such as Nanoaccess, Nanoquest, Nanoed etc. web sites about nanotechnology can provide distance learning and like Nanotruck trucks and Nanoworld game parks are structuring to raise the societal awareness (Nanobulletin08, 2009).

4.2 STATUS OF NANOTECHNOLOGY EDUCATION ALL AROUND THE WORLD

Describing qualification involvements in the beginning level and supporting the improvement of the require skills to take advantage of the commercial promising of nanotechnology has been described as a significant subject in a lot of countries. Nevertheless, considering nanotechnology there are a very few studies can occur to integrate university curricula. Although wide in range count of research universities provide courses in the area; currently, few universities provide degrees in nanotechnology (Luther, 2004). At present, several universities in the USA, Europe, Australia and Japan present elective graduate programs in partnership with research centers in nanoscience and nanotechnology (Ozel and Ozel, 2008). Various universities provide undergraduate practice in interdisciplinary center also. Additionally, there are studies for nanotechnology programmes and degrees in other countries as like Germany, Denmark or Switzerland (Luther, 2004).

In the US establishing research centers, federal and state governments, academic institutions, industry and for profit and nonprofit organizations have promoted collaborations. A number of research centers promote a related graduate program in the patron university also. Besides the organizations like NSF, DoD, NIH, DARPA, etc. in the areas of nanotechnology and nanoscience academic member remote and conduct survey programs foundation (Ozel and Ozel, 2008).

As Kristen Kulinowski stated, who works in Rice University as professor and interested with Nanoscience and Nanotechnology Education, US has many research centers and these centers investigate to integrate Nanoscience and Nanotechnology subjects in K-12 (Kindergarten through 12th grade) curricula. For instance, the Center

for Biological and Environmental Nanotechnology (CBEN) and NSF Nanoscale Science and Engineering Center in Rice University, study with current curriculum and indicate teachers how nanotechnology can be used in their required curriculum to demonstrate concepts. The new Nanoscale Centers for Learning and Teaching are communicating education researchers, teachers, and nanotechnology researchers to respond essential questions on the most influential road to make contact between nanotechnology and students in grades 7 through 16. These centers will generate education professionals for the new generation to specialize in nanotechnology education that will help as a possibility for everyone making educational outreach in these fields (Kulinowski, 2006). NSF declared a new program, Nanoscale Science and Engineering Education in 2003 which involving four parts high school, informal education, undergraduate education and education and learning centers. And nearly 7,000 students and teachers have been trained by NSF in FY 2003 on the supply side (Roco, 2003).

In numerous European countries, contemporary learning and teaching tools on nanotechnology are presently tested in the NANOYOU project and financed by European Commission. In the international literature, there are plenty of approaches and schedules for NST (Nanoscience and Technology) education on science and engineering teaching. Moreover, combining these subjects in the formal education system, all over the world NST education requirements have generated numerous informal outreach projects also. These kinds of enterprises contain educational web-based tools that are managed by the public, as well as science centers and museum exhibitions (Laherto, 2010).

4.3 IMPORTANCE OF NANOTECHNOLOGY EDUCATION

Currently nanotechnology is globally thought as 21st century technology (Meyyappan, 2004) and during the former decade, the area of Nanoscience and Technology has become related to significant societal, economic and ethical topics progressively. As a result of this progression, it has been often suggested that NST education should be supplied at various level. These requests have been built from a diversity of perspectives by a variety of supporters, containing governments and public administrations, industry and trade, civil organizations, social scientists, nanoscientists, engineers and educators of science and technology (Laherto, 2010).

Nanoscience education field is barely incoming subject matter (Sullivan et al., 2008). Besides, it is needed to support interdisciplinary links for reflecting harmony in nature. It is predicted that nearly 2 million nanotechnology employees will be demanded all around the world by 2015 (Roco, 2003). These numbers will be promoted with addition to 5 million employees (Healy, 2009).

In numerous situations, the demand of NST education has been definited with related to *scientific and/or technological literacy* concepts that have maintained notably efficient in curriculum development projects all around the world. The main idea in these assertions is that whole citizens will soon required a kind of “nano-literacy” to navigate some of the significant science related to subjects with their daily lives and society. According to some, these requirements have also been responded not just introducing education of NST at the academic plane, but also it can be succeeded by establishing numerous projects targeted at integrate NST topics within the primary and/or secondary school curriculum (Laherto, 2010).

Reports which considering nanoscale research, oftenly emphasized the essentialness of interdisciplinarity (Laherto, 2010). And because of nanotechnology is very interdisciplinary, an interdisciplinary curriculum, which encompasses a wide understanding of main sciences combined with information and engineering sciences appropriately, is fundamental for nanotechnology education (Ozel and Ozel, 2008). NST has been connected with the reductionalism idea of the natural sciences, in a word the scientific interest targets not just connecting with quantum mechanics, solid state physics, inorganic chemistry and molecular biology one by one, however it is aiming to combine them together equally or at least partially at the nanoscale (Laherto, 2010).

To create both of learning-centered and knowledge-centered environments nanotechnology should be considered in and out of the classroom. Activities that promote creative and critical thinking and life-long learning should be prior because the technology is progressing very fast. In nanotechnology education interactive learning must be the hallmark. Using the internet, students can attend in laboratory surveys and nanotechnology research development projects all around the world. Additionally, to get hands-on practice, students should be designed the occasions for studying directly with all of launched nanotechnology research centers. For educating and training students in Nanotechnology area, university faculty members must cooperate with industry: It is

very demandable that a group of academic members which specialize in proper disciplines to teach nanotechnology courses. Additionally, government, university and industry bodies should grow a cooperatation among themselves (Ozel and Ozel, 2008).

The area will demand the important scientific progresses in the direction of integrative concepts of the wide diversity of laws and stables which used in analysis of nanosize recently. A wide plan is required to train school children and technicians, fund students and postdoctoral fellows which will tempt some qualified students available. When planning these kinds of practices, school authorities and school boards must be include at every stage from the beginning. To continue funding, long-time planning and convenient dialog with the people and administrative and lawmaker government departments are essential for systematic alternation (Roco, 2003).

Whoever speaks about subjects of nanotechnology with middle school students can tell you that nanotechnology subjects attract them. This attraction should be take advantage of cause further attention in scientific researches (Kulinowski, 2006). Extending nanoscience concepts in elementary schools is planning by NSF in the near future. A team which consisted from academic institutions has started to procure local and long-distance outreach programmes involving experiments in laboratory by internet and television in the area of nanoscale science and technology. Academic institutions without powerful basis and public at large, outreach activities are addressed K±12 (Roco, 2003).

Considering comprising nanoscience and nanotechnology into K-12 education, there are multiple subjects. Teachers stated the curricula which currently they are teaching is very crowded and can not attach matters which not piece of their needed content standards on the negative side. NNIN researches of teachers joint a current (National Science Teachers Association) NSTA annual meeting and these meeting showed that teachers have few or no information regarding nanotechnology and do not understand how nanotechnology could be integrated in their science lessons. These teachers stated that if they attached nanoscale science and engineering in the lessons they required professional improvement assistance in period of professional workshops and online support. They also reported that attaching these lessons in their classroom instructions, these lessons should be integrated with involved science learning standards (Healy, 2009).

The most widespread apprehension is that the approaching deficiency of researchers, engineers and other professionals, who experted in nanoscale subjects (Laherto, 2010). Linking and synchronizing elementary, middle/high school, undergraduate, graduate and ongoing education is another difficulty. And, this is essential that connection, generalization of affirmative conclusions and adaptation into the conventional curriculum. And nanoscale engineering and science regimentation in K-12 and university education is required (Roco, 2003).

The effect of nanoscience until now has arrived to the students of higher sciences and engineering related to the subject, which is a deficiency. These progresses should be given to all of the students to teach them more. These students will be appealed to support upcoming scientific effort or to make aware that what kind of risks might be found in the upcoming technology as citizens. We can provide exhilarate to more students to choose science and engineering career and encourage these gateway courses by submitting these inspiring concepts at the plane of entrance science courses (Sullivan et al., 2008).

Michael Roco (2003), senior advisor for nanoscale science and engineering at NSF, described the specific requirements for nanotechnology training and education as follows:

- Stimulate a system approach for teaching nanoscale science and engineering at all levels.
- To emphasize interdisciplinarity; participate of the same main concepts from one area to another. And generating the media in all related disciplines from biology, electronics and materials to engineering system adaptation, for nanoscale R&D progression.
- Containing titles on system architecture and manufacturing developments at the nanoscale, underline a combined scientific treatment in simulation and theory.
- Providing promoted interest to technical and ongoing education.
- For reaching the requested social applications, active outreach from universities and other research centers is indispensable. As much as to industry innovation, international aspects and general public, the outreach is forwarded to K±12, ongoing and undergraduate education.

- Connection and dissemination of the affirmative conclusions, their synchronization into the conventional curriculum and institutionalization of nanoscale science and engineering in education of K±12 and university are some of the challenges. Because of its system, unifying and interdisciplinary method of research, engineering must have very important role in this road.

NST openly represents whole key characteristic of “postmodern science” and a new world of information is be covered, will be need by nanotechnology (Laherto, 2010 and Roco, 2003).

CHAPTER 5

BIOTECHNOLOGY EDUCATION

Biotechnology is a wide term for a group of technologies which based on living systems and/or biological processes applications for solving problems (Garrett, 2009). Particularly, discovery of recombinant DNA technology by the end of 20 century and the first decade of the 21 century, there was very important development of biological sciences (Darcin, 2011). Biotechnology has great potential for effecting human life as one of the rapidly improving field of current scientific and technological disciplines (Altiparmak, 2010).

Biotechnology is a strong, enabling technology at present, with applications which have the potential to make fundamental changes on lots of industrial sectors, as well as for changing our essential understanding of what it means to be a human being. It is fastly building itself, becoming a cornerstone of modern science, and one of the major scientific fields of public concern presently. Biotechnology produces health and environmental advantages and is arranged to perform an increasingly important effects on the economies of nations and on their citizens' lives all around the world, while its development and growing continue with a high-speed (Garrett, 2009). The National Research Council Canada (2005) states:

> It is believed that the transformative nature of biotechnology eventually will impact most sectors of the global economy. Biotechnologies are often regarded as the most significant S&T (science and technology) of the current century, with impacts exceeding those of information and communications technologies (National Research Council Canada, 2005).

Over the last decade the fast developments in biotechnology have came into prominence with medical innovations and other following novelties like genetically modified products in food industry. Biotechnology develops several subjects regarding ethics, tolerable risk limits and practicability of the new products. In parallel to biotechnological innovations, students need to have more knowledge about economic, social and ethical applications like genetic engineering, genetically modified food, cloning and other aspects of biotechnology (Usak and Erdogan, 2009). Biotechnology needs less physical infrastructure of heavy industries of the past, but surely detected that from laboratory workbench to the capital suppliers, the capabilities of scientifically trained people, who understand science and business both, at all grades. It is building important domain of knowledge in modern science and biology education reform at school level is answering demand of qualified staff capacity (Schuster, 2008).

The future headmen of the “BioCentury” should be trained warranting their advancement of the various fields of science and technology which will produce innovations. Significance of Mathematics, Physics, Chemistry, Biochemistry, Molecular Biology, and Genetics is irrefutable. However, they are suggested to provide their colleagues, which our graduates can study effectively in teams, solve actual problems, read and write about complicated scientific and social subjects and become influential and reformer leaders and have efficient critical thinking abilities and skills to combine massive amount of information. Biotechnology has a particular relationship with public opinion related the social effects of science and technology, as the “applied” part of the Life Sciences. Our students reach real world of all ideas, from well-considered and data-based, to the completely false and produced. Current instances of scientific debate; stemcell studies and genetically modified products, with the social organizations agendas, which are not obligated and limited by scientific data or logical discourse. The debate includes little critical assessment, intellectual probity or regardful dialoge (Schuster, 2008).

Sure as death improving scientific literacy of young people was important components of science education (Usak and Erdogan, 2009). Recently, aspects of biotechnology and some related learning experiences are being integrated and are built into science curriculum around the world (Garrett, 2009). Scientific literacy defined by Organization for Economic Co-operation and Development (OECD) as follows:

Scientific knowledge and development can be used for not just understanding environment and nature but for contribution to conclusions that affect them (OECD, 2006). And in parallel of these, as a member of community, for the making of better individuals and social choices, people should be informed about science and technology (Darcin, 2011).

We prepared lesson plans aiming the training and raising awareness about biotechnology of 5th grade elementary school students(see appendix B). They can be implemented, and their effects can be evaluated just like nanotechnology lesson plans.

CHAPTER 6

LITERATURE SURVEY

There are few researches in education of nanotechnology and biotechnology in K-12 education. Researches about nanotechnology education are comparatively much academic education especially nanotechnology education in engineering and majority of biotechnology education researches are in high school level.

Ak (2009) prepared a master thesis “Implementation of Nanotechnology Education in the High School” aiming to comprehend students to nanoscale and considering these building science-technology and society connection. They used library-searching method for indicating how nanotechnology was adapted in high school curriculum. And they presented twenty-one activities in work sheet form for high school students. As a result of literature library researches they suggested reducing nanotechnology to high school education level from university.

Ekli (2010) carried out a master thesis for investigating 6th, 7th and 8th grade students’ basic knowledge and opinions about nanotechnology and attitudes towards technology in relation to some variables. They worked with 23 public school locations in Mugla, Turkey total 1396 students, 708 girls and 688 boys. They used attitude scale and questionnaire to collect data. They found majority of students have positive attitude against technology and nanotechnology and they had a little information about nanotechnology and they mostly gained these informations via television.

Batt and friends (2004) investigated effects of *It’s a Nano World* a hands-on museum and hands-on traveling exhibition which prepared for K-3 students and prepared a summative evaluation report. The main goal of the exhibition was for children 5 through 8 learning about the world that is very small to see with bear eyes. They used a

pre-post study to investigate what content children gained and exit interviews to find children's understanding of concepts introduced as well as any misconceptions associated to the learning goals. Evaluators conducted a two-part summative evaluation at the Science center, a hands-on science museum in Ithaca, New York, and at Innoventions Epcot®, in Lake Buena Vista, Florida. They found that the visitors stated *It's a Nano World* was a fun, inviting, and engaging hands-on exhibition. Pre-test and post-test findings showed increased understanding of key science vocabulary. For example, "cells" and "nano".

Blonder and Dinur (2012), prepared a paper offering a nanotechnology program which was prepared for high school students with student centered pedagogy. They used student interview and semantic differential questionnaire and evaluated students motivation and perceptions. They worked with thirty-six girls aged 15 in two 10th grade classes. They had found students were grateful the title of LED (Light-emitting Diode) and explored that it enhanced their motivation to learn more about LED, nanotechnology and chemistry. And the study indicates that at the high school level teaching advance scientific subjects such as nanotechnology is not an unimportant task.

Yurick (2011) prepared a Ph.D. thesis named "Effects of Problem Based Learning with Web-Anchored Instruction in Nanotechnology on the Science Conceptual Understanding, the Attitude Towards Science, and The Perception on Science in Society of Elementary Students". They explored the effects of Problem-Based Learning (PBL) with web-anchored instruction in nanotechnology elementary students' science conceptual understanding, the attitude towards science and the sense of science in society. They used a mixed approach method. Nearly two and a half weeks subjects (N=46) participated. Subjects participated with from the southeast part of the United States 5th grade elementary school students. Pretest-posttest and interview was used for evaluation. A web-anchor in nanotechnology was used in the study as intervention. A pre-test was managed science conceptual understanding and for attitude towards science after the intervention. Then a Nano Post-Interview made with purposefully selected 6 interviewees. Pre-test, post-test data were analyzed with a paired t test. The results of t tests indicated that for science conceptual understanding and attitude towards science were significant. Two independent rater coded and analyzed interview data and emerging themes. "Risk and Benefits" and "Solves Problems" themes emerged from interviewee

students' responses to perception in sciences in society questions. "Risks and Benefits" theme suggests subjects have a positive perception that nanotechnology comes with risk and benefits to society. And "Solves Problems" themes suggests subjects have a positive perception that nanotechnology is managed by society' requirements and can be using for solving society' problems. They reached the consequence, PBL with web-anchored instruction in nanotechnology had a positive effect on science conceptual understanding of subjects, attitude towards science and society' science perception. Additionally, learning of nanotechnology can be succeed in elementary school students and nanotechnology can be integrated in science curriculum studies at the elementary school level.

Altiparmak and Yazici (2010) investigated 8th grade elementary school students' biotechnological concepts and processes of learning and using recently designed materials and activities and published an article. Pre-test and post-test, attitudes scale, achievement tests and word association tests were used. The sample of the study consisted 30 students. 12 of them were in control group and 18 of them were in experimental group. Experimental group practiced material design with team activities and control group practiced traditional instructional design. There was no significant difference between pre-test of control and experimental groups achievement test results, but there was significant difference between post-test results. Regarding attitudes test there was no substantial difference between pre-test and post-test results of groups. And in mind map control group made more connection between concepts. Findings indicate that these kind of designed hands on activities provide great positive affects of students' learning, academic achievement and persistency of knowledge. And attitudes against biotechnology affected in a positive way also.

Usak and friends (2009) investigated Turkish high school and university students' attitudes toward biotechnology and prepared an article "High School and University Students' Knowledge and Attitudes Regarding Biotechnology". The sample of the study consisted 352 high school and 276 university students. Biotechnology Knowledge Questionnaires (BKQ), which has 16 items, and Biotechnology Attitude Questionnaires which has 37 items and five likert were data collection tools. More than half of all participants answered correctly half of the knowledge questions. They found that, there was no statistically remarkable difference between university and high school students

biotechnology knowledge but with respect to almost all items, high school students appeared to have more information than university students. They had similar knowledge about meaning of biotechnology processes. University students had more positive attitude toward biotechnology. Students' most positive attitudes were towards genetically modified plants, and their most negative attitudes were towards genetic manipulations on genetic modification productions, shopping genetically modified products, animals at risk of ecological consequences of cultivating GM plants, and civil awareness of genetically engineered foods.

Garrett (2009) prepared a master thesis named "Professional Development for the Integration of Biotechnology Education". This retrospective study focused on a group of educators teacher and laboratory technicians from three separate schools and their development into modern biotechnology educators through their participation in professional development events over a five year period (2003-2007). These schools selected about participating the study on the basis that their staff had joint at least one biotechnology professional workshop through 2003-2007. The staff had attempted learning experiences implementation and they acquired from the professional development. Three different school from three different area participated to study. A large inner city secondary school (A) located in the capital city of the state, a large secondary school (B) located in the second largest city of the state, one large regional city secondary school (C). They used one-on-one interview, documents and focus group discussions to collected data. For the interview and focus group phases, individual participants purposefully selected from these schools. These educators had experienced a range of professional development initiatives and integrated biotechnology in their science curriculums.

They founded the educators approved integration of contemporary biotechnology into science curriculum there was a supportive infrastructure for these, but most of educators identified that although having joined biotechnology professional development workshop back, particularly in the content knowledge, laboratory skill acquisition, proper pedagogy knowledge and curriculum management fields they need to have more acquisition to more complete including of this contemporary science. Additionally the educators thought that educated, skilled and careful laboratory technicians were

important to biotechnology education at schools. They suggested that there was a requirement developing a biotechnology professional development model.

CHAPTER 7

METHODOLOGY

7.1 INTRODUCTION

In academic and professional fields, qualitative research has been increasingly used (Holliday, 2002). Qualitative research allows for in depth study of educational phenomena and teacher and students' experiences thereby providing rich answers to research questions. Interviews and observations are commonly used as empirical tools in qualitative research. The researcher can reach reality fields can not reached in different circumstances like subjective practice and manner of people (Denzin and Lincoln, 2005).

In the current study, we conducted qualitative research to evaluate the effects of the nanotechnology lessons. In this qualitative study, I developed instructional materials for teaching nanotechnology and biotechnology to elementary school students. I implemented nanotechnology lesson plans and materials in a fifth-grade classroom. I have been working as an elementary school teacher for seven years, and I conducted the present study during my graduate studies in biology. To examine the effectiveness of nanotechnology instruction and progress of the students in understanding of nanoscale science and nanotechnology at the elementary school level, I collected data through semi-structured interviews and observations. In this chapter, I will describe the development of the instructional materials, the lesson plans and their implementations, participants, data collection procedures, and data analysis methods.

7.2 DEVELOPMENT OF INSTRUCTIONAL MATERIALS

In the development of the lesson plans, I greatly benefited from two websites that include instructional materials for teaching nanotechnology to K-12 students:

www.nanooze.org and www.nanosense.org. Both of them are supported by US National Science Foundation. In parallel of the lesson plans, I prepared power point slides that contain various pictures from internet. Lesson plans were adapted to fifth grade by removing or simplifying some subjects. For example; we removed the subject about types of microscopes and simplified the subjects about the definition and properties of nanotechnology.

7.3 CURRICULUM (LESSON PLANS) DEVELOPMENT PHASES

PHASE 1:PLANING

Identify Issue/Problem/Need

Nanotechnology is a technology in progress and is spreading like wildfire. It is being used in fabrics, glasses, cars, electronics and nearly every field of daily life. And biotechnology is one of the very important fields that is rapidly developing and currently discussed by the public. In parallel of these progresses, nearly all of the students hear and see nanotechnological and biotechnological products in their daily lives. However, there are no subjects about nanotechnology in the elementary schools and biotechnology subjects are starting from 8th grade in Turkey currently (Web Page, 18). We considered that today's elementary school students will become future's nanotechnology and biotechnology customers and workers so they need to have accurate knowledge and raised awareness about these subjects.

Curriculum Development Team

Nanotechnology and biotechnology are very new and multidisciplinary subjects. They are mostly related to sicence, technology, and mathematics. The role of the team members was to develop appropriate course content for fifth-grade students. The team consisted of two members: I, Umran Atabas a primary school teacher and working for 7 years and a graduate student in the Biology Department and Assistant Professor Z. Ebrar Yetkiner Ozel.

PHASE 2: CONTENT AND METHODS

We thought that students needed to learn what nanotechnology and bitechnology were, scientists' areas of investigation in these fields, the kinds of products invented using nano- and bio-technology, and what these technologies would bring to our daily lives. We expected students recognize products on the market and in progress produced using nanotechnological and biotecnological approaches.

Before organizing the content, we determined intended outcomes and titles of lessons.

Intended Outcomes

NANOTECHNOLOGY LESSONS

LESSON 1: What is Nanometer?

To realize nanometer is so small that it can not be seen by bear eyes
To guess which objects are in nanoscale

LESSON 2: Nanotechnology from Nature

To realize nanotechnology samples from nature
To give examples for nanotechnological samples from nature
To give examples of products made by inspiration from nature

LESSON 3: Water Permeable-Repellent Nanotechnoology

To realize there are hydrophobic and hydrophilic molecules in nature
To give examples for water permeable and water repellent nanotechnological products

LESSON 4: What is Nanotechnology?

To be aware of nanotechology as a science that deals with very small objects that can not be seen by bear eyes
To develop sensitivity for nanotechnology concepts

LESSON 5: Nanotechnology in Our Daily Lives

To give examples for nanotechnological products on the market and in progress
To realize nanotechnology can be harmful if we do not use it consciously

BIOTECHNOLOGY LESSONS

LESSON 1: Let's Make Yoghourt

To develop ideas about the methods scientists use to produce the desired products
To give examples of application in the field of biotechnology.

LESSON 2: A General Overview Of Biotechnology

To exemplify biotechnological applications
To realize biotechnological applications in our daily lives to raise the quality of our lives.

LESSON 3: What is GMO?

To give examples of biotechnological applications and their utilities.
To explain benefits and harms of GMOs through examples.

LESSON 4: Ethical Issues About Biotechnology

To develop ideas about how ethical biotechnological applications on humans are

Content Selection

We chose the contents considering 5th grade students' cognitive levels. Our goal was to raise their awareness and curiosity about nanotechnology and biotechnology.

There are no subjects about nanotechnology and biotechnology in the fifth grade cirruculum in Turkey or many other countries. In relation to nanotechnology; we think it was proper to have an idea about nanometer. Students already know the units of measurement so they could easily learn a new measurement. They had to know nanometer was so small that it can not be seen by bear eyes. Thus they could be

introduced nanotechnology subjects, then it was proper to learn animals and plants using nanotechnology and they had to build connection between nanometer and the subjects. They should be able to give examples of organisms that use nanotechnology. Then, they had to learn about water permeable and water resistant matters, establishing a connection with the properties of organisms that use nanotechnololgy and nanotechnological products. In this section they had to perceive the connection between nanotechnology and manipulation of properties of matters.

They should develop sensitivity against the concept of nanotechnology and realize nanotechnological products on the market and in progress. They need to be aware of the requirements to use nanotechnological products consciously; otherwise, they could be harmful. Finally, they should be able to realize that nanotechology was a key and ever growing and spreading technology for the present and the future.

In relation to biotechnology; students should know the meaning of biotechnology. We aimed teaching the meaning of biotechnology by having them make yoghourt, which they often eat in their daily lives. They should also know about biotechnological applications and benefits of these applications. GMOs is a current and oftenly discussed subject, about which they should be informed. We must their raise awareness about benefits and harms of GMOs. Finally, they should have idea about ethical issues of biotechnological applications like cloning and GMOs.

Design Experiential Methods

I used lecturing, question-and-answer, discussion, and experiment methods to conduct the lessons. We determined the teaching methods considering students' cognitive level, content, goals, and the class size. In the lectures, I used pictures about the subjects like nanoproducts, organisms that use nanotechnology, or properties of nanomaterials. We used concrete examples from students' environment such as a sheet of paper that was nearly 100.000 nanometer thick or conducted experiments such as spilling water on their uniforms and nanofabric. We used many pictures of nanoproducts, nanometer, properties of nanomaterials, carbon nanotubes, and so forth. We prepared hands-on activities for deep understanding. We discussed issues such as "Why do scientists make investigations or explorations?"

Hands-on Activities:

We wanted students to keep a strand of hair and forecast its thickness in nanometer. After listening to students' predictions, we explained it was nearly 100.000 nanometer thick.

We brought nanofabric to class and conducted experiments in groups. Students spilt over water on their uniforms first and then on nanofabrics. Finally, they compared the difference between the results of these two applications.

PHASE 3: IMPLEMENTATION

Preparation of Curriculum Materials

There are many websites with lots of pictures and experiments for teaching nanotechnology to K-12 students and kids. Books about teaching nanotechnology subjects to K-12 students are also available. In the preparation of lesson contents, we greatly benefited from www.nanooze.org and www.nanosense.org websites.

Curriculum Implementation

We implemented the nanotechnology lesson plans for nine hours in one week. On the first day, we had one class hour and on the other days two class hours. As a result of the implementations, we think these subjects must integrated into science, technology, and mathematics curricula.

PHASE 4: EVALUATION AND REPORTING

We evaluated effects of the lessons with interviews and observations. Five days after all the lessons were over; we conducted interviews with 15 students. We directed nine questions to students about the lessons and asked their ideas about nanotechnology lessons. Then, we analyzed the answers by coding them into themes and subthemes.

Additionally, an observer attended lessons and took notes about the contents of the lessons, performance of the teacher, and students' reactions. Besides the interviews, we analyzed observer notes and coded them under themes and subthemes titles. Finally, we stated our results and suggestions accordingly.

7.4 PILOT STUDY TO IMPROVE MATERIALS AND THE MAIN STUDY

Considering nanotechnology subjects were very new for students, we determined a pilot study would be helpful to improve teaching materials. We conducted a pilot study to make necessary changes in the lesson plans, to promote the effectiveness of the lessons, and to enhance student motivation and understanding. The pilot study was conducted in a different public school. Considering the interviews and observations in the pilot study, we revised the lesson plans, interview questions, interview time, number of interviewees, and made other alterations accordingly.

7.5 CLASSROOM INSTRUCTION

We prepared five lesson plans. Lesson one lasted one hour, and the others lasted two hours. I will briefly explain key points, content, and the implementation of lesson plans.

Lesson 1: What is Nanometer?

I used lecturing, question-answer technique, experiments and discussion in the lesson. I started the lesson by asking how we could measure the distance from Istanbul to Kars (I used Kars as the example because majority of the students were from Kars). Then, I asked how we could measure our school garden, our notebooks, and, finally, our fingernails. After listening the answers, I asked these questions;" Why do we need different kinds of measurements?", "Can we need another measurement unit to measure smaller or bigger things?", "How can we measure viruses or different kinds of very small things?" After listening their answers, I introduced nanometer. I wanted a strand of hair from students and wanted them to guess how much nanometer the thickness was. Students tried to guess, and I gave the correct answer. Then I used examples like: A sheet of paper is about 100.000 nanometers thick; an ant is approximately 1.000.000 times bigger than a nanoparticle; your fingernails grow one nanometer every second. I supported the lecture with pictures. Finally, I mentioned that many events in our environment occur at the nanoscale. For example, we can smell the food through nanosized molecules that flow in the air and reach our nose.

Lesson 2: Nanotechnology from the Nature

In this lesson, I gave examples about new discoveries that scientists made by inspiring from the nature. I used noticeable examples for kids, such as the surface structure of lotus flowers or sticky nanohairs of geckos, to raise their interest. I supported the lecture with pictures of organisms that use nanotechnology. We did an experiment: first, students spilt water on their uniforms and experienced that the uniform got wet. Then, they spilt water on nanofabric and experienced its unusual properties.

I used nanofabric and picture of lotus flowers together to have them realize that scientists were inspired from lotus flowers when they invented nanofabric. I asked, "Why do scientists make discoveries?" and we discussed about the question. At the end of the lesson students realized that there are much more things to discover in nature.

Lesson 3: Water Repellent Nanotechnology

I wanted examples from students about matters that get wet and that do not get wet. I explained water repellent or permeable structures in nature. To get their attention and improve comprehension, I called this situation "matters that like water" and "matters that do not like water." Then, I asked "Can we make matter structures that are water repellent or permeable?" I gave examples about manipulating structures of matters to make them "like water" or "do not like water" (e.g., nanotechnological products such as nanofabric, antimist glasses, nanodye, and nanoceramic). I emphasized that scientists can manipulate properties of matters using nanotechnology. I wanted examples from the students about matters that they would like to turn into water repellent or water permeable. Then, I asked "What kind of advantages may these discoveries provide us?" I promoted the idea that "Technology can make our lives easier."

Lesson 4: How Does Nanotechnology Work?

I started the lesson asking students if we could turn water permeable matters into water repellent or water repellent matters into water permeable. After getting students' responses, I had them watch a video about atoms and a video showing the magnification of aluminium more than 1.000.000 times. After watching and talking about the videos and atoms, I asked, "Can we change properties of matters? And how? "

Then I asked “What is nanotechnology?” and ”What is nanotechnology for?” After a discussion with the students, I explained the answers and then I introduced some nanoproducts that they can experience in their daily lives, such as nanodye, nanofabric. Later I mentioned about unusual properties of nanomaterials like nanogold, buckyball, and carbon nanotubes. We watched a video named “Unbreakable and flexible glass.” I emphasized that materials that are in nanoscale can have unique, unusual properties and can surprise us. At the end of the lesson I gave the students a scenario which named “Year: 2045” (see appendix A) (Web Page, 19) and asked them to read.

Lesson 5: Nanotechnology in Our Daily Lives

In the beginning of the lesson we talked about the scenario, how our world would be after 23 years from now, and which nanotechnological products they wanted to use. Then, I referred to currently marketed nanoproducts. I introduced many nanoproducts in progress, and we talked about how we could use these products and what the functions of these products were in our daily lives.

Then I asked, “Can nanotechnology be harmful?” After listening the answers, I explained nanotechnology could be harmful like any other technologies if we used it unconsciously, and I gave some examples. Then I emphasized that nanotechnology was progressing very fast, and in the next decade we would be using many nanoproducts. Consequently, there would be need for millions of nanotechnology workers all around the world.

7.6 OBSERVER NOTES

Dr. Serkan Ozel attended our first, third, and fifth lessons as an observer and took notes about our study. We analyzed observer’s notes and coded them into themes and subthemes as follows.

7.7.1 Themes

7.7.1.1 Interest

Students gave correct answers about nanometer scale measures of samples used and mentioned in previous lessons. They remembered many examples mentioned in former lessons. When the teacher made a mistake, students corrected it. They asked why they were learning about nanotechnology.

7.7.1.2 Wondering About The Subjects

Students asked many questions during lessons such as: How many nanometer is one millimeter? Is there a unit of measurement bigger than kilometer? What is nanogold for? Does antimist sprays' effect last forever? Are there nanotechnology products on the market? Does nanotechnology provide benefits to animals? Does nanospray turn normal fabric into nano fabric permanently? Are unbreakable and flexible glasses made from carbon nanotube bulletproof? Do unbreakable glasses work in earthquakes? How do they penetrate nanobots into our bodies? Will we feel nanobots when they are entering into our bodies? How nanobots will turn back from our bodies? How many kilometers can space elevator rise? How much time does the elevator need to go to the space?, How many people will go to the space with a space elevator at once?"

7.7.1.3 Examples from Students

After we watched a video about big world of atoms, a student said: "The sun appears small to us, and we think it is small." Indeed, this was a very good example to understand how big things can appear and be thought as small.

7.7.1.4 Students' Challenges

When the teacher explained that one meter is one billion nanometer, the students had difficulties to read one billion.

7.7.1.5 Suggestions for The Teacher

There was a few visual materials in the first lesson but using concrete examples were profitable to comprehend the subject. Directive yes/no questions made it easier for

students to answer. It was a good introduction to begin with familiar examples from students' environment. While the class was watching the unbreakable glass video, a couple of students said there was a trick in there. The teacher could conduct examples that she used in other lessons and could emphasize that unexpected things can happen in nanotechnology. Students asked lots of questions about nanobots, which could be conducted to investigate about the subject.

7.7.1.6 Motivation

Students' attention was very high in the course. Many of the students were eager to respond questions and participate in the lessons. They also asked their own questions.

7.7 PARTICIPANTS

This study was conducted in a fifth-grade classroom in a public primary school during the spring semester of 2011-2012 academic year. There were 47 students in the classroom: 24 boys and 23 girls. The school was located in a low-income and noncentral district of Istanbul, Turkey. Parents of the students mostly graduated from elementary school and had low-paid jobs. As a result of income levels of their families, the students were unlikely to attend social and cultural activities outside of the school. The main teacher stated that many of them were eager to learn and be successful in the school, and very few students were uninterested in the lessons.

We chose implementing the nanotechnology lessons with fifth-grade students because by the time of the study they had been taking science and technology courses for more than a year. Thus, it was expected that they had some background information to be able to understand the nanotechnology lessons. In addition, fifth-grade students have still childlike wonder and curiosity about their environment, and they are excited to learn about innovative ideas. At the same time, we expected that fifth-grade students express their ideas articulately so that they would be able to provide clearer and more meaningful answers than lower grade students during the interviews.

There was an observer in three of five class. The observer was an academician at a large public university in Istanbul. He took notes during the lessons. I interviewed 15 of

47 students when all the lessons were over. The interviews were recorded and then transcribed.

I will introduce the interview participants on the basis of the classroom teacher's and my observations.

Interested 1: He was a very responsible, respectful, self-esteemed, hard-working, and clever student. His parents were very attentive to his school achievement.

Interested 2: She was very social, and she had leadership skills. She was always very interested in the lessons and attended classes. She did not study that much but she was successful.

Interested 3: His teacher thought he had very high emotional intelligence. He was a very articulate and successful person. His parents were very attentive to his school achievement.

Interested 4: She was very clever and very successful at school. She would act as the peacemaker between her friends. Her family was very poor.

Uninterested 1: He came from a crowded family. He was not interested in the classes. He did not do homework. However, he was clever, and he did not have any discipline problems.

Uninterested 2: She was a self-enclosed person. She obeyed the school rules, strived to succeed in the class, and did her assignments. Nevertheless, she was not successful in the school.

Uninterested 3: She was a low-achieving student and never participate in the classes. She was also very irresponsible as a student.

Uninterested 4: He never participated in classes, and he was uninterested in the lessons. He was very naughty and quarrelsome.

Random 1: He was a very clever, calm, and intrinsic person. He obeyed the rules and got on well with his friends. His parents were very poor.

Random 2: He was a very calm and intrinsic person. He always seemed uninterested in the classes but when you asked him about the lessons, he knew the answers.

Random 3: He was a very quiet and low-achieving student. His teacher thought his educational level was very low – his achievement level was comparable to a second grader. His father was in prison.

Random 4: She was a hard-working, successful, and social student. Her teacher thought she had high emotional intelligence.

Random 5: She was an intermediate level student. She obeyed the rules.

Random 6: She was very honest. She strived very much to accomplish in the class; nevertheless her level was low. Her friends loved her.

Random 7: His level was medium. He did not study enough. His friends loved him. His father was very attentive to him.

7.8 PROCEDURE

First of all, I met the principal of the school and teacher of the implementation class, and I got their permission for the study. With a letter of application, lesson plans and materials, I consulted for permission from Turkish Ministry of Education to practice the study in public schools. After obtaining permission from the Turkish Ministry of Education, I conducted the main study in a public elementary school with 47 fifth-grade students. I conducted interviews with 15 of 47 students after all the lessons were over. I implemented the lesson plans from 26.03.2012 to 30.03.2012. The instruction took one class hour on the first day and two class hours on the remaining days. I finished the lessons in five days. After all of the lessons were over I chose the interviewee students considering my observations during the classes as four interested, four uninterested, and seven random students. I conducted the interviews with students from 05.04.2012 to 06.04.2012. I did not declare interviewee students before the interviews, and I called them one by one.

I followed the lesson plans and took notes about students' reactions during the lessons. One observer from a university attended 3 of 5 lessons and he took notes about me, reactions of the students, and the lesson plans. Finally, I analyzed students' responses in the interviews and observer notes by coding them into themes and subthemes.

7.9 DATA COLLECTION

I chose 15 students and interviewed them one week after all nanotechnology lessons were over. During the interviews, I asked nine questions to each student, and I directed "What would you want to know more about nanotechnology?" question to very interested students only. The questions were as follows:

1. What were the most attractive things for you in nanotechnology lessons?
2. What do you remember about the organisms that use nanotechnology?
3. What comes to your mind when you hear the word nanotechnology?
4. What size of matters does nanotechnology deal with?
5. Can we manipulate matters? And how?
6. What kind of benefits do nanotechnological products provide us?
7. Which nanotechnological products would you like to use? Why?
8. Can nanotechnology be harmful? How?
9. What was the difference between nanotechnology lessons and your other classes?
10. What would you like to know more about nanotechnology? (This question was asked only to the very interested students.)

7.10 OBSERVATIONS

Dr. Serkan Ozel who works as an academician at a large university attended the first, fourth, and the fifth classes as an observer. He took notes about the teacher, lesson plans, students, and the process during classes.

Additionally the main teacher of the class said she was curious and wanted to listen the lessons. She attended all of the lessons, took notes, and gave her observation notes and ideas to me after each class.

7.11 MAJORS

My advisor Prof. Dr. Fahrettin Gucin, my co-Advisor Assistant Prof. Dr. Zeynep Ebrar Yetkiner Ozel, as an observer Assistant Prof. Dr. Serkan Ozel, and as the researcher teacher and graduate student myself, Umran Atabas, we conducted the current study with 47 elementary school students.

7.12 ANALYSIS

The interviews are analyzed using content analysis. First I transcribed interviews listening to the tape recorder. Like Samardzija (2011) stated, the first step in the content analysis was using inductive analysis to determine if there were any related patterns or themes in the students' answers. Then, I read the answers and questions many times and determined related patterns and/or themes. I began collecting the answers of the students under determined titles of themes and subthemes. When I collected the related answers under themes and subthemes, I decided to combine some themes and divided some themes into subthemes. For instance, initially I arranged "organisms" and "inspiration from the nature" themes separate but when I read them one more time, I decided to combine them. I organized the initial main theme of "nanometer" as a subtheme of the "smallness" theme. I combined "easiness" and "benefit" themes as one single theme. I put together "interested" and "wonder" themes with "I heard it for the first time" theme and generated one single theme. I united "hydrophilic" and "hydrophobic" themes because I realized that students used them together constantly. In addition, I added some themes when I read the answers of the students again and again; for example, I added "self-cleaning" theme, after I organized the themes.

CHAPTER 8

FINDINGS

After transcribing all of the interview data, students' responses were interpreted using thematic analysis. Thematic analysis is a qualitative data analysis method that allows for the identification and analyses of themes or patterns within the data. Thus, students' responses in the current study were coded under various themes using bottom-up approach, meaning the themes were derived as the researcher read the data. This chapter explains the themes and subthemes that were identified.

8.1 WHAT IS NANOMETER?

When students were asked "What were the things that attracted you the most in the nanotechnology lessons?" or "What comes to your mind when you hear the word nanotechnology?" students' responses mostly included the nanometer concept. One of the interested students said: "I learned that nanometer is smaller than millimeter." Most of the interested students referred to the nanometer concept with "Most powerful microscope of the world" which was mentioned in the lessons (i.e., Atomic Force Microscope). The students stated, "We can see the nanosize matters with the most powerful microscope of the world." Most of the students counted nanometer with other units of measurements like following "nanometer, millimeter, centimeter".

8.2 I HEARD IT FOR THE FIRST TIME

Most of the students mentioned that nanotechnology was a new subject for them. They stated that "We did not know about nanotechnology, and we learned it with you." They also indicated that these new ideas were attractive: "These lessons were fun

because, we learned things that we never heard before;" "We were very excited when we heard it for the first time. Learning more about these subjects satisfied our curiosity."

One of the interested students (interested 4) stated that: "These lessons were different, more attractive and helped the development of my imagination more." Another student (random 7) expressed his interest by saying: "These lessons were a little different, I have never heard this stuff before; and it challenged me some."

8.3 BECAME INTERESTED

Whether interested, uninterested, or random, nearly all of the students indicated that they became interested in nanotechnology subjects, particularly when they were asked "What was the difference between nanotechnology lessons and another lessons?" One of the interested students (interested 1) said: "I learned small particles and more interesting things like combining of nanotechnology and becoming more powerful than steel, nanotube." One of the students commented that, "This lesson was fun. We did not know nanotechnology before but we learned different things."

The other random student (random 1) stated: "We learned nanotechnology enough, we learned a subject which we had never known or never heard before. At first we were very excited and wondered about what kind of things would be covered. We had not known how small and as small as we could not see with eyes nanotechnology was, we thought it was big but after we learned about it, our curiosity is satisfied."

And one of uninterested (uninterested 2) students said: "It was different, very different, there were facilities that change the life."

8.4 MANIPULATIVE CHARACTERISTICS OF MATTERS

When students were asked, "Can we manipulate the matters? And how?" all of the fifteen students answered: "Yes, we can." In addition, some students referred to manipulation when they were asked, "What were the things that attracted you the most in the nanotechnology lessons?" and "What comes to your mind when you hear the word nanotechnology?" They frequently reflected on the nanofabric sample that was used for

the hands-on activity in the class and stated: “With nanotechnology, we can turn water permeable fabric into water repellent fabric.” One of uninterested students described the hands on activity as follows: “Nanotechnology changes the matter; for example, fabrics, you demonstrated us, we spilled water on the fabric, the water repellent glass.” And another uninterested students said: “We can change the properties of matters but I can not remember.” Some of the students reflected on a sample from the scenario “Year: 2045” which was used in the fifth lesson - Nanotechnology in Our Daily Lives, saying, “We read a scenario, dresses were changing their colors.”

Two students mentioned about atoms with these words: “We can change the properties of matters by changing their atoms.”

8.5 ATOMS

Students mentioned atoms frequently as they talked about manipulation of matters, nanoscale, and the most attractive nanotechnology subjects. They stated that they remembered, “Atoms were so small that they could be seen with Atomic Force Microscope.” One interested student said, “Nanotechnology is about very small things, smaller than atoms.” This was a mistake because atoms are not in nanoscale individually. An atom has a diameter of about 0.1 nm. Another student responded to the question of “Nanotechnology deals with which size of matters?” by saying “atoms and virus”. A random (random 1) student explained how we could manipulate matters as follows: “We can change properties of matters by changing their atoms, for example we can turn hydrophilic glass into hydrophobic glass, we can change a normal dye to dirt-proof dye by changing its atoms.” Another student said, “We can manipulate matters by changing their structures, atoms. For example, fabric, glass, dye”.

8.6 FUTURE

Most of the students talked about future when they were reflecting on the benefits of nanotechnology. They stated nanotechnology would make our lives easier and will grow more in the future. One of the uninterested students (uninterested 4) mentioned: “Nanotechnology simplify our works and direct next generations to scientific

researches," and another student stated that "I would like to use nanotechnological fabric suit when I go to a meeting in the future."

Students also referred to future developments in nanotechnology: "It is on going and will grow more technology;" "Many things have been produced, and more will be produced with nanotechnology."

8.7 SMALLNESS

All of the students frequently used the smallness concept when responding to nearly all of the questions. When they were asked "What comes to your mind when you heard the word nanotechnology?" they answered: "a very small unit;" "very small particles" or "small existences, even smaller than small".

They mostly emphasized how small nanometer is: "I remember the most powerful microscope in the world, nanometer is smaller than millimeter;" "Nanometer is very small particles." One student said: "I remember there are units of measurements smaller than millimeter. There are flexible glass, antifog glasses, nanometer is very small particles, will be done nanobots which so small that can not be seen with eyes."

Students emphasized smallness when they were asked, "What size of matters does nanotechnology deal with?" Some sample answers were: "Nanotechnology deals with small sized matters;" "organisms that are very small, that can not seen with eyes;" "We can only see them with the biggest, highest microscope;" "very small even smaller than atoms".

There was some misunderstanding about the concept of smallness. Some students said nanotechnology deals with very small things even smaller than atoms. That was a mistake because atoms are smaller than nanoscale individually. Many students particularly mentioned that nanotechnology deals with small organisms.

Subtheme Microscope

All of the students frequently associated smallness with microscope. One interested student (interested 3) said, "Nanotechnology deals with matters of sizes that can not be

seen with naked eye. We can see them with the most powerful microscope in the world." One of the uninterested students stated, "For example, how can we see bacteria? We can not see the smallest organisms with microscope; they can be seen with the most powerful microscope in the world."

When asked, "What do you remember about the organisms that use nanotechnology?" a student answered: "Very small things, how can so many things fit into small things? How could we see them, if microscopes did not exist?"

One student said: "I remember the most powerful microscope in the world, and nanometer is smaller than millimeter." Another student stated, "Atoms are so small that they can be seen with atomic force microscope."

A misunderstanding among students was that they associated the microscope with only small organisms. Indeed, I made the same observation during the pilot study. I believe the cause of this problem is that they had used microscopes just for seeing small organisms, and they could not comprehend that non-living things like elements (see appendix A: Lesson 3) could also be seen with microscopes.

Subtheme Nanometer

Students mentioned nanometer and smallness together often and emphasized: "We can not see these small things with our naked eyes," and "We can see the nanometer size only with the most powerful microscopes of the world." Some of the students mentioned nanometer with nanoproducts they remembered from the lessons, such as, "Nanoglass, nanometer, nanofabrics, nanoglasses, dye" or "Flexible glass, antimist glass; nanometer is very small particles. Scientists will invent small robots that can not be seen with bear eyes." Another random student used nanometer with other units of measurements and said: "nanometer, centimeter, millimeter".

8.8 EASINESS-SIMPLIFY

This theme mainly appeared as an answer to: **"**What kinds of benefits do nanotechnological products provide us with?" questions. They frequently responded to this question using ideas and examples from our classes: "Let us assume we went to a

meeting and something spilt on our dress, it does not stain; then, you washed it with “nanomatik clothwasher ball”, without detergent.” Or, “If something spills over a carpet, the carpet does not become dirty;” “Nanodye can clean itself with water;” “We can defend ourselves with nanotechnological shield in a war;” “Coats do not get soaked with nanotechnology;” “Surgeries can be operated more easily with nanobots.”

One of the uninterested (uninterested 2) students mentioned about advantages of nanoproducts for people with disabilities: “Nanotechnology provide easiness to clean dresses and carpets. Some people can have disabilities, and it provides easiness for them. I have a nephew with a disability.” One student asked in the lesson: “Can nanotechnology provide benefits to animals?” Most of the students connected easiness with future and stated nanotechnology will make our lives easier in the future.

Subtheme Benefit

An interested student (interested 3) stated: “Nanoproducts has gained favor in our daily lives. For instance, if somebody tries to rob a bank, he or she can not break the glass and return empty-handed.” A random student mentioned about nanoproducts: “I would like to use all of them in my daily life because many of them are profitable”, and another student (random 1) stated, “If we use them [nanoproducts] regularly and enough, they can be very useful in our lives.”

8.9 MODELING FROM THE NATURE

Students adverted scientists took model from the nature. They gave examples that we used in the class, and surprisingly they could remember nearly all of the examples. Some of the students mentioned modeling from the nature when they talked about interesting and attractive aspects of nanotechnology: “The most attractive things for me were Namib Insect and the fabric that was made by modeling from the nature,” and “This lesson was fun. We learned different things; we did not know about nanotechnology. Also sprays they made them by modeling from something …”(She did not complete her sentences).

Some students referred to modeling from the nature when they were asked, “What comes to your mind when you hear the word nanotechnology?” They said: “It was

modeling some organisms, there was Namib Insect, which lives in an African Desert, the way that no one can survive," "They invented nanofabrics via modeling hydrophobic properties of lotus leaves," and (random 5) "They produce stuff for us by modeling plants and animals."

8.10 SCIENCE AND TECHNOLOGY

Most of the students stated, "Nanotechnology is a technology in progress," and related nanotechnology with "developing technology and producing new things". They emphasized, "These lessons were interesting because we are interested in technology and technological devices."

One of uninterested (uninterested 4) students said he or she thought of "Science and studies that scientists do," when he heard the word nanotechnology. Another random student (random 5) stated a parallel thing saying "science".

8.11 HYDROPHILIC-HYDROPHOBIC (PERMEABLE OR REPELLENT WATER)

Many of the students gave examples of hydrophilic and hydrophobic structured organisms and products together in parallel of "Lesson 2: Water Permeable-Repellent Nanotechnology" They referred to Namib Insects and mentioned those insects had hydrophilic and hydrophobic parts. Further, the students explained that; "Nanofabric was made by modeling hydrophobic property of lotus leaves," and "Nanotechnological carpets, coats do not got wet because they do not allow water in." Students frequently adverted to hydrophobic and hydrophilic nanotechnological products when they were asked; "Can we manipulate the matters? And how?" One of the students (random 5) answered, "We can change the properties of matters, for instance, turn water permeable fabric into water repellent one, when we squeeze spray to armchairs it transforms nanofabric, nanotechnological dye can clean itself," and "We can change our hydrophobic dress to hydrophilic with nanotechnology." An uninterested student (uninterested 2) said, "Nanotechnology changes matters for example fabric; you demonstrated it, we spilled water." One of the interested students stated: "I would like hydrophobic cell phone," and one uninterested students "I would like to use

“nanomatik”, nanodye and nanofabric, if I will go somewhere and spill something on my dress, the water will not be absorbed – it will be gone.” An other uninterested student said: “If there is no water repellent shoe, our feet get wet but with water repellent shoe our feet do not get wet.”

8.12 SELF-CLEANING

Many students referred to self-cleaning properties of nanotechnological products as they were describing the ease that nanotechnology would bring to our lives. One of the interested students stated: “Glasses do not show dirt, they clean themselves with water.” Another random student stated, “Buildings can stay clean, if nanodye is used.” One student said similar things: “If you use nanotechnological dye instead of normal dye, you dye once and it removes dirt itself.” When answering a different question, one random student (random 1) adverted: “We can turn dye into dirt repellent dye by manipulating its atoms.”

8.13 CAN NANOTECHNOLOGY BE HARMFUL?

When I asked the question “Can nanotechnology be harmful?” nearly all of the students responded, “Yes, it can be.” Two of the interviewees gave an example that I emphasized in lesson 5: “It may be harmful if we use it carelessly. For instance, if we respire a nanotechnological detergent (cleaning material), it may damage our lungs.”

An interested (interested 3) student emphasized commercial aspects of nanotechnological products and added: “Some people use the label “nano” for stuff that are not nanotechnological and thus cheat others.” Likewise, one of uninterested (uninterested 4) students emphasized the cheating aspect: “If the products are not developed by scientists, it may damage a family, it may cause cancer, or it may contain virus because they are not hygienic.”

One of the uninterested students stated nanotechnology was not harmful and said: “In my opinion, no.” One uninterested student mentioned: “Someone can make a robbery with a color changing car, then can change its color and license plate.”

In parallel to the lessons, some of the students generalized and related the subjects with harms of other technologies and mentioned about harms of other technological products like computers. A random (random 2) student said; “When we look at the computer much, our eyesight may fail and we may be addicted to cartoons;” “Sometimes it may be harmful and some time it may not be, nanocomputers may break our eyesight;” “Computer has nano particles and can disrupt our eyesight but benefits of nanotechnology are more than its harms.”

One of the random students related the harm of nanotechnology to the manipulation of matters: “In my opinion it may be harmful, for example, nanotechnological spray may cause eyesight disrupt just as changing properties of the fabric.”

CHAPTER 9

RESULTS AND DISCUSSION

DISCUSSION

This study contained in-depth qualitative information about nanotechnology education in elementary schools. Forty-seven fifth grade students participated in the study, and 15 of them were selected as interviewees. To our knowledge, there are very rare qualitative researches in the field of nanotechnology education in schools, and very little research has been conducted about nanotechnology and biotechnology education in elementary schools. Researches within K-12 education have mostly been done at the high school level. Findings of the current study consisted of lesson implementations, observations, and interviews with students.

Former researchers have prepared activities for high school students and offered advices for high school nanotechnology education (Ak, 2009). There are only a few articles that provide information and ideas about nanotechnology education for elementary school students (Ekli, 2010). These studies also offer some activities to educators. However, to our knowledge there are very rare researches that implemented nanotechnology activities and lesson plans at the elementary school level. This study is very rare because we implemented nanotechnology lesson plans and activities in an elementary classroom and used qualitative research to examine its effects. By implementing lesson plans in a class and analyzing students' responses, we filled a gap in the field of nanotechnology education and provided new aspects for investigations in nanotechnology and biotechnology education in schools.

The interviewee students responded the questions using the following themes: What is nanometer?, I heard it for he first time, Became interested, Manipulative characteristic of matters, Atoms, Future, Smallness, Easiness-simplify, Modeling from nature, Science and technology, Hydrophilic-Hydrophobic (Permeable or Repellent Water), Self-cleaning, Can nanotechnology be harmful?

Nearly all of the students connected nanotechnology with smallness. Most of them referred to “We can see very small things with the most powerful microscopes in the world. And all of the students gave nanoproducts examples from the market or in progress. And the most remember organism which using nanotechnology was Namib Insect. Some students used “atoms” concept when they were talking about manipulation of characteristic of the matter, and they described atoms as “small things inside the matters.” The main teacher stated that the students encountered the concept of atom for the first time in nanotechnology lessons, and they could learn it quickly.

The students were very interested in technology because they used computers actively. They really did appreciate and were excited about learning this new and interesting technology, and they asked many questions about all of the subjects. Nanobots, space elevator, carbon nanotubes, anti-mist nanospray and nanofabric were most attractive examples. Students were curious about these products and asked many questions like following:

“How will they insert nanobots into our bodies?”
“How many people can go to space with space elevator at once?”
“How long do effects of nanospray persist?”

The students were bored when I used the same example twice, and they would say “We saw it before.” In further lessons, they quietly remember nearly all of the subjects, examples, pictures and activities which be used in previous lessons. They insistently asked: “Can we use nanometer in our daily lives?”, “How do nanoproducts work?”, “What are their functions?”, “Are they on the market?“, ”Are they expensive or not?”. The students were very surprised when I explained that nanoproducts are commonly available. They were interested in nanotechnology as a science and asked “Can you tell us names of the scientists who study nanotechnology?” They would not follow the lesson as effectively when I used the lecturing method. Despite there was a projector

constantly in their class and their teacher used it prominently, they were very much engaged in the lesson and entertained when I used pictures and video films.

In the lessons and interviews most of the students remembered nanofabrics and their water and stain resistant properties. I think this was mainly due to the hands on activities, which allowed them to remember those examples in the long term. Students at this age learn better with concrete things rather than abstract things.

Students could easily predicted that nanotechnology can be harmful, if we did not use it carefully or did not pay attention to product labels. They stated nanotechnology was a technology in progress, and we would use many more nanotechnological products in the future. They gave examples like “nanomatik clothwasher ball” which they encountered in their daily lives or advertisements. During the interviews they tried to make connections with what they learned and heard in the lessons.

During the first, third and fifth lessons an observer from a university and during all of the lessons the main teacher of the class stayed in the class, observed and evaluated effects of the lessons, performance of the researcher teacher, and reactions of the students. The observer took notes and the major teacher stated her ideas an in interview at the end of lessons. All of these contributions are included in this chapter.

The observer referred to students’ interests and challenges in the lessons, examples provided by students, suggestions for teaching, and the motivation themes. At the end of the lessons he stated that students were very interested in nanotechnology classes. The students could answer the questions easily, remember examples from previous lessons, and showed high motivation. He suggested more hands-on activities in the lessons based on the level of the students. The teacher of the class, who has worked as primary school teacher for 18 years, stated students were more interested in the nanotechnology lessons than other lessons. Further, some students with low motivation in other classes were very interested in the nanotechnology lessons. She said “I am amazed. I thought the subject would be very high level for fifth grade students, and I thought they would be bored from the lessons and they would not listen, but I saw that they have extraordinary motivation and interest in the lessons. Even on the third day of the implementation the students were still listening and joining the lessons. After the implementation of the nanotechnology lessons, I can say that nanotechnology subjects can be integrated in, particularly, science

and technology curricula conveniently. The observer found the performance of the researcher teacher very good. Supporting the classes with visual materials proved to be productive. We can easily realize from students' responses that the subjects were understood; students used scientific and terminological language when answering questions.

SUGGESTIONS FOR EDUCATORS

Nanotechnology is a multidisciplinary subject that needs to penetrate into the education system because it will develop with great speed and spread various areas of our lives in the near future. Nanotechnology subjects also correspond to General Goals of Turkish Board of Education. With the current study we showed that nanotechnology can be included in the elementary school curriculum, and students can understand and develop awareness about nanotechnology.

When adapting nanotechnology in the elementary school curriculum, however, it is important to carefully consider students' cognitive levels. The subjects are very abstract, especially for elementary school students so we should teach these subjects using visual materials like videos and pictures, experiments, and hands on activities. At the primary school level (7-12 age) because of their cognitive development stage (Piaget and Inhelder, 2000), we should choose more concrete examples and subjects, like nanoproducts; further, we should allow students to have first hand experience with nanotechnological products or examples of nanotechnology in nature. These subjects are not familiar to most of the elementary school students so they may lose attention easily. Thus, we need associate nanotechnology with their everyday lives by starting lessons with examples from their daily lives and discussing potential effects of nanotechnology to their lives. From my observations in my nanotechnology lessons I observed that such an introduction was helpful for getting students motivated and eager to participate in the course.

During the lessons, teachers can explain mechanisms and functions of nanotechnological products in a simple and basic manner and talk about the availability and prices of nanoproducts, which would get students interested in owning one of these products. Based on my observations organisms that use nanotechnology can be

appropriately used in lower grades because children are interested in such organisms; thus, they become motivated, and learning occurs more naturally. Another important point that should be constantly emphasized during teaching is the manipulative characteristics of matters at the nanoscale because these subjects is basis of nanotechnology.

At higher grade levels more abstract and complex subjects, such as types and mechanisms of microscopes used in nanotechnology, properties of nanomaterials, or how nanoproducts works, can be taught. As we teach about nanotechnology, we should emphasize potential risks and hazards of nanotechnology or biotechnology and try to develop a national awareness about these new technologies.

Because nanotechnology is a scientific subject, we should mostly conduct experiments in the class. We should emphasize that nanotechnology is a science, and there are many scientists who do interesting and high impact research in nanotechnology. It would be of interest to students if we mention the names of a few scientists and introduce their research and probably the types tools (e.g. microscopes) they use.

In parallel our findings and researches, what we suggest here is not adding nanotechnology or biotechnology as a stand-alone lesson to the curriculum, especially K-8 curriculum. Rather, both nanotechnology and biotechnology can be integrated into the science and technology curriculum, and nanoscale can be appropriately included in the mathematics curriculum.

LIMITATIONS

The current study was conducted at a public elementary school and was implemented in a fifth grade classroom of 47 students. Thus, the results of the current study are limited to the current sample although the results provide teachers and researchers with valuable insights about the teaching and learning of nanotechnology at the elementary school level. The students were interviewed by the researcher, whom they did not know before. Thus, students' responses during the interviews could have been affected by the environment, their mood, excitement, or some other factors.

The implementations were limited with the lesson plans, their contents, and instructional methods. Out of the 47 students in the class, interviews were conducted with 15 students, and the thematic analyses were limited to those students. Interviews were done five days after the implementations of the lessons, and students responded based on what they remembered at the time of the interviews. All of these factors could have affected the findings.

FUTURE RESEARCH

This study aimed training and raising awareness of elementary school students about nanotechnology and biotechnology, and we implemented our lessons in a fifth-grade classroom. Further researchers may explore the teaching and learning of nanotechnology lessons in upper level elementary classes such as 6th, 7th or 8th grades. Future studies may also implement biotechnology lessons in elementary schools and examine teaching and learning experiences.

Training teachers in nanotechnology and biotechnology is very important for teaching these subjects within the K-12 curriculum. Future researchers can prepare professional development opportunities for teachers in these subjects and examine their effects. In the current study we conducted interviews with students; future researchers can interview teachers to provide information on their ideas or experiences about nanotechnology and biotechnology education. And in the light of the current study other new technologies can be comfortably implemented in elementary schools.

Gifted and talented students can be more interested and attentive to these subjects. Thus, future research may consider to prepare more in depth lesson plans for gifted students. We can establish technoparks to introduce nanotechnology and biotechnology subjects to kids and adults. We can prepare to introduce these technologies to kids and adults and provide national awareness about them. Indeed, examples of such websites exist in the world: www.nano.gov, www.nonesense.org, www.nanooze.org

CONCLUSION

We conducted a qualitative study for inform elementary school students and raise their awareness about nanotechnology and biotechnology subjects. We prepared lesson plans and implemented nanotechnology plans in a fifth grade class at a public school. We evaluated the effects of the study with interviews and observations. As a result of the study we can say that these subjects can be comfortably taught in elementary schools. Students did not encounter problems in understanding the subjects. However, we should always be careful about students' cognitive levels when preparing lesson plans. The students asked many questions during and even after the lessons, and they had very great motivation and interest in the lessons. Particularly videos and experiments attracted great attention. Most of the students stated that they appreciated learning these subjects, and they wanted to know more.

There are many sources to prepare lesson plans about nanotechnology and biotechnology subjects. A large number of them are in English. Particularly, the web sites for kids are very beneficial. According to our observations and conversations, teachers have serious deficiency of knowledge for teaching these subjects, and these subjects are hard and complex. Preparing an education program for teaching of nanotechnology and biotechnology and developing teachers' skills and positive attitudes towards these subjects is crucial.

In the current information and technology age, educators should update curricula constantly so that we can prepare students for the future. Students need to adapt to their age more easily and catch opportunities. They should also be careful about risks and disadvantages of new technologies. These should be some of the main goals of education.

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APPENDIX A

NANOTECHNOLOGY LESSON PLANS

LESSON 1

CHAPTER I

TIME: 40 minutes

LESSON: WHAT IS NANOTECHNOLOGY?

CLASS: 5

CHAPTER II

GOALS: 1. To realize nanometer is so small that it cannot be seen by bear eyes

2. To guess which objects are in nanoscale

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, question-answer, experiment, discussion

INSTRUCTION TOOLS: A strand of hair, a sheet of paper, blackboard

LESSON AREA: School, class

LEARNING-TEACHING PROCESS

The lesson is started with the question how we could measure the distance from Istanbul to Kars (I used Kars as the example because majority of the students were from Kars). Then, how we could measure our school garden, our notebooks, and finally, our fingernails, questions are directed. After listening the answers, I asked these questions; “Why do we need different kinds of measurements?”, “Why we do not prefer to measure our fingernails with meter or kilometer?”, “Can we need another measurement unit to

measure smaller or bigger things?", "How can we measure viruses or different kinds of very small things?" Students' answers are listened, then nanometer is introduced.

Experiment: One nanometer is a kind of measurement unit that uses to measure extremely small things. Nanometer is as small as that we cannot see without special tools. Teacher wanted from the students to keep a strand of hair from their hair and feel width of it then, a strand of hair is wanted from students and asked them to guess how much nanometer the thickness is. Students try to guess, and the correct answer is explained: Width of a hair strand is nearly 100.000 nanometer. If we though put 100.000 point side to side on the width of this hair strand, between of collateral two points is nearly one nanometer wide. Wanted from students to keep a sheet of paper from their notebooks and try to guess how much nanometer the thickness is. After the predictions, explained this wide nearly 100.000 nanometer. Then used examples like: A sheet of paper is about 100.000 nanometers thick; an ant is approximately 1.000.000 times bigger than a nanoparticle, the lecture supported with pictures.

Nanometer is a unit of measurement and is used for measuring extremely small sized structures. It is mentioned that many events in our environment occur at the nanoscale. For example, we can smell the food through nanosized molecules that flow in the air and reach our nose. A water molecule is smaller than one nanometer. A medium bacterium is nearly 1000 nanometers size. Hundreds of bacteria become in our hands, look our hands. Could we see them? Despite they are average 1000 nanometer we could not see the bacteria. Could we see one nanometer length? Students' answers are listened. Our fingernails grow one nanometer every second. Watched our fingernails together, could we see their growing? Could we see one nanometer with our bear eyes? Students discussed the questions. After the discussions, it is explained nanometer is extremely small measurement unit and we can see it only with very powerful microscopes.

CHAPTER III

EVALUATION

1. What comes to your mind when you hear nanometer word?

2. To exemplify to matters which measuring with nanometer.

INTEREST WITH OTHER SUBJECTS: We can establish a connection with measurement units subject of Mathematic lessons.

LESSON 2

CHAPTER I

TIME: 40+40 minutes

LESSON: NANOTECHNOLOGY FROM NATURE

CLASS: 5

CHAPTER II

GOALS: 1. To realize nanotechnology samples from nature

2. To give examples for nanotechnological samples from nature

3. To give examples of products made by inspiration from nature

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, question-answer, discussion, experiment

INSTRUCTION TOOLS: Projection, nanofabric, video, students' uniforms, water bottles

LESSON AREA: School, class

LEARNING-TEACHING PROCESS

We have mentioned about nanometer in previous lesson. Nanotechnology interests with matters that have from 1 to 100 nanometer size. The scientists who interested with nanotechnology are making new discoveries and producing new tools by using these very small matters.

Have you ever seen some lizards which are able to climb the walls even ceilings? Are you wondering about how can they do this? In this lesson, we will obtain information about how nature using nanotechnology. We can see many of

nanotechnology samples in nature. Geckos can climb the walls. How can they do this? Geckos have thousands of nanometer sized sticky hairs under their foot. They are able to climb the walls even ceilings by using these sticky nanohairs. Scientists made inventions modeling Geckos' sticky nanometer sized hairs: http://www.indirimtreni.com/urun/magic-nano-pad--sihirli-kaydirmaz-pad.aspx the video is watched and discussed.

Photographs of lotus flower leaves are showed via projection. It is mentioned that these leaves have a very interesting property, they hate from water. How? Lotus leaves have water repellent characteristic and water drops fall down over the leaves collecting dirt of leaves. Have scientists made what kind of inventions modeling from lotus leaves water repellent property? They invented waterproof fabrics and dyes. Is it got wet when we spilled water on our uniforms? Questions are discussed, then nanofabrics are introduced to students. Choosing a volunteer student spilt a little water to his/her uniform and then nanofabric. It is shown all of the students that it did not get wet. Nanofabric and picture of lotus flowers are used together to have them realize that scientists were inspired from lotus flowers when they invented nanofabric. Scientists get inspiration from lotus leaves made water and stain proof fabrics and dyes. Water and stain repellent nanofabrics, pants and self-cleaning nano dyes are in market at present.

Experiment: Be distributed nanofabrics and water bottles to each student. First, students spilt water on their uniforms and experienced that the uniform got wet. Then, they spilt water on nanofabric and experienced its unusual properties.

Blue Morpho Butterflies is another organism, which use nanotechnology. Blue Morpho Butterfly pictures are showed students and emphasized their beautiful colours. They count between most beautiful butterflies because of their colours. Actually, they are colorless and this beautiful blue colour does not their colour. How could we see them like this? This realized via nanometer scale structures in their wings. These nanostructures refracting the light in a different way and thus Blue Morpho Butterflies look like this beautiful colour. Is it interesting? What kind of inventions can make modeling these butterflies property?

Scientists search nanotechnology in the nature and try to understand. They searched Geckos foot and realized how their sticky nanohairs work. Why? Why do

scientists make discoveries? The question is discussed. At the end of the lesson students realized that the scientist make discoveries for providing easier life and increasing the quality of our daily lives and there are much more things to discover in nature.

CHAPTER III

EVALUATION

1. Exemplifying samples about organisms which using nanotechnology.

2. What kinds of inventions have made modelling from organisms?

3. Are there more discoveries, which used for the benefit of people, in the nature?

LESSON 3

CHAPTER I

TIME: 40+40 minutes

LESSON: WATER REPELLENT NANOTECHNOLOGY

CLASS: 5

CHAPTER II

GOALS: 1. To realize there are hydrophobic and hydrophilic molecules in nature

2.To give examples for water permeable and water repellent nanotechnological products

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, question-answer, discussion

INSTRUCTION TOOLS: Projection, Nanofabric

LESSON AREA: School, class

LEARNING-TEACHING PROCESS

Examples are wanted from students about matters which get wet and that do not get wet. It is explained that there are water repellent or permeable structures in nature. Examples are produced with students.It is asked to students: If your notebooks have water repellent structures, would it be easier for you? To get their attention and to improve their comprehension, these situations are called “matters that like water” and “matters that do not like water”. Can we make structures of matters water repellent or permeable? Examples are given about manipulating structures of matters and making them “like water” or “do not like water” (e.g., nanotechnological products such as nanofabrics, antimist glasses, nanodyes, and nanoceramics). Scientists can manipulate properties of matters by using nanotechnology. Thus, water and oil repellent, stain

resistant fabrics and sprays which turn normal fabrics into stain resistant fabrics and dyes and cleaning themselves with water are produced. Pictures of nanotechnological dyes and fabrics are shown to students from projection. Which organism could scientists modelled for inventing these products? Which properties of lotus flowers could they benefited from? Questions are directed to students. Lotus flowers and nanofabrics pictures are shown to establish connection between them by students. Experiment which is done in previous lesson is remembered and mentioned to make some private applications that scientists make surface of the fabric water and stain resistant. Have you ever experienced not wear your dirty dress for the next day? Nanofabrics are water and stain resistant and when we spilt on our dresses they do not become dirty; thus, we do not need to wash it.

Do you see dirty buildings around? Is it easy to clean outside of buildings? When water drops of rain fall down from the surface of buildings, the rain water collect the dirts and nanodyes provide the outside of building stay clean. Thus, outside of the buildings can easily be cleaned. Have you ever lose your sight because of mist in winter? Has your father ever lose his sight when driving because of mist or wipers? Questions are directed to the students. It is mentioned, by force of antimist and water resistant glasses, drivers can see the way even in heavy rainfalls. Scientists achieved to turn glass, which do not like water, into antimist glass which like water by using some private methods. Antimist glasses pull water to themselves, the water distributing equally on the glasses and water cannot collect some areas. Thus, the glasses do not mist up. Antimist glass pictures are shown via projection. Have you ever seen nanofabric and nanodye ads on TV? Teacher and students mentioned the ads about nanotechnological products.

Examples wanted from the students about matters that they would like to turn into water repellent or water permeable. Then, what kind of advantages may these discoveries provide us? Question is directed to students: “Technology can make our lives easier.” idea is promoted. The scenario “Year: 2045” is distributed to students and wanted them reading it before next lesson.

CHAPTER III

EVALUATION

1. Exemplify the matters that like water and matters that do not like water.

2. Exemplify the inventions which scientists made altering water repellent or water permeable properties of matters.

3. How these inventions make our lives easier?

READING TEXT

SCENERIO YEAR:2045

Ayse asked to the household artificial intelligence as she walked to the bathroom: “Alladdin how am I doing?” The system answered by recognizing her voice: “Ayse, if you place your hand in the wall panel, I will do a quick check-up for you.” Ayse said it was okay and put her hand to the screen of household artificial intelligence and meanwhile she said “You can open the shower for me”. “Ayse, you should take a vitamin tablet after having a shower. You are starting to show signs of a cold. All your physical functions appear fine. Additionally, your heart pulses slightly raised.” Ayse said okay and she went to the bathroom. She said: “My heart pulses rate is raised because I am going to an invitation with my husband tonight.” She was knowing that the artificial intelligence did not care if she response or not but it was seem to have a personality. When she was relaxing in shower, a signal came from communication implant where below her ear: “Fatma is calling you. Would you like to answer or not?”, “Yes, please.”

-Hi Ayse. How are you?
-I am fine. I am in the shower and getting prepared for the invitation.
-What color are you going to wear tonight?
-I will wear blue but I could change color when we start dancing. What about you?
-I will wear red but I will flip to green when we dance.

They talked fifteen minutes before Ayse said “Disconnect it”. After toweling off and taking vitamin tablet, she started to makeup. It felt the nanocosmetics like her second skin. These cosmetics have sunscreen properties at the same time.

Ayse was going to an invitation with her husband Levent. Levent has broken his leg when he plunged into the pool. But it had healed quickly after the doctor injected the nanofiber diamond-coated prosthesis to support the bone until it healed. Now, Levent could go to the gym regularly. After the gym he took a shower and got dressed. He placed screen of artificial intelligence of the gym for check-up. The school’s artificial intelligence called “mother” by kids. A few moments after he went into shower, it chirped: “Levent Akyol there is no problem and all of your body is good.” This message

was also saved in the folder of gym teacher. The teacher checked this folder and took information about medical conditions of the students. Levent dressed up quickly and went to his car and pressed his thumb against to the keyspot on the door to unlock it. Levent was proud of his first car. Like his dad's car it had lightweight nanotube reinforced fiber body that was the same color all the way through, so even deep scratches were not shown. Levent's car captured some electricity from solar conversion and braking, and he fully recharged it by plugging into the grid, usually at home.

When he put his hand to the steering wheel, there was a few pause to as the car checked her breath to make sure he had not had anything that would harm his driving. And the car checked his prints and a few moment later green light came on and he drove. After a while later, his communication implant signaled a call from his mother. Levent's mother works in a laboratory that producing less side affected and more influential new nanocapsul drugs. After talking with his mother Levent came to home, parked and plugged into grid for charging his car. The car was covered with solar converter paint which recharged the battery with sunlight. Electricity was generating by solar converters placed in large areas like deserts. He entered home and put his dresses on the bed, his stomach growled and he went to the kitchen for a snack. It might be late by the time the food was served at the invitation, he prepared a small sandwich. Afterwards he took a mouthful of Nanodent. The nanomachines in the mouthwash recognized particles of food, plaque and tartar and lifted them from the teeth. No one have not used toothbrush and toothpaste since Nanodent produced.

Ayse was not ready yet. Levent went to the kitchen and took a glass of cherry juice. When he drank it, a little cherry juice poured out to Levent's white shirt. Meanwhile Ayse came with her blue dress and smiled relaxing way. "My shirt produced from stain and water proof nanofabric and it is stain-proof." said Levent. Ayse wiped the shirts and all of the cherry juice was gone. Thus, Levent did not change his shirt and did not waste time, water, detergent and electric for it. They got into the car and went to invitation (Adapted from: http://nanosense.org/activities/sizematters/index.html).

LESSON 4

CHAPTER I

TIME: 40+40 minutes

LESSON: HOW DOES NANOTECHNOLOGY WORK?

CLASS: 5

CHAPTER II

GOALS: 1. To be aware of nanotechology as a science which deals with very small objects that can not be seen by bear eyes

2.To develop sensitivity for nanotechnology concepts

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, Question-Answer, Discussion

INSTRUCTION TOOLS: Projection, Video, Scenario Text, Ruler

LESSON AREA: Class, School

LEARNING-TEACHING PROCESS

The scenario "Year: 2045" is talked and discussed with students for 15 minutes. Then, it is asked to students that whether we could turn water permeable matters into water repellent or water repellent matters into water permeable. After getting students' responses, a video about atoms and the video showing the magnification of aluminium more than 1.000.000 times is watched: http://www.dailymotion.com/video/x4mv3m_zoom-into-aluminium_tech#rel-page-7.
After watching and talking about the videos and atoms, it is asked: Can we alter properties of matters? And how? It mentioned, actually, all of natural events and objects start in a very small size. For example, considering the water that we drink every day, extremely small constituents unit compose water or the desk we sit on, very tiny

constituents unit compose the desk. Properties of mattes like water was liquid and wood was solid are originated from these very small constituents and their interaction with each other.

Nanotechnology is interested in very small sized events and matters which constituent matters and give them different properties. What is the meaning of nano? The word of "nano" comes from “dwarf” in Latin. Nanoscience is interested in very small sized matters and nanotechnology develops devices by using applications in these small sized matters. Nanoscience and nanotechnology are interested in 1 to 100 nanometers size. Purpose of nanotechnology is recognizing and understanding of these very small sized matters and developing new and high technology materials with them.

How small is nanometer? Let’s realize it. We need rulers to keep a ruler in our hands and to look between 0 to 1 millimeter. Can you see how long one millimeter? Now, we think to put 1.000.000 points with equal interval in these length. A length of side by side two points show us one nanometer length. Could we see this length with our bear eyes? Scientists use nanometer measuring length as small as we can see with some special microscopes. Nanometer is smaller than head of a pin, wide of a our hair strand and our cells. Scientists who work in nanoscale said that we cannot even compare nanometer with these lengths. Certainly, it is tinier than we can see with our bear eyes.

“What is nanotechnology?” and “What is nanotechnology for?” questions are asked. In short, nanotechnology will become a concept we often hear. Maybe you will work on a field which is related to nanotechnology. Would you like it? Nanotechnology use in from nutrition to dressing, from energy to communication and from cosmetics to medicine. Nanotechnological medicines, water repellent fabrics, self cleaning dyes, detergents and many more products are currently becoming in market. Teacher is mentioned that she has seen “nanomatik clothwasher ball” in ads. Have you you watched the ad? Have you seen another ad which containing nano word? Questions are directed and students mentioned about nanotechnological products in market. After a discussion with the students, the answers are explained. Then, some nanoproducts introduced via projection that they can experience in their daily lives, such as nanodye, nanofabric. Later, it is explained about unusual properties of nanomaterials like nanogold, buckyball, and carbon nanotubes. A video named “Unbreakable and flexible glass” is watched. It is emphasized that materials that are in nanoscale can have unique, unusual properties and

can surprise us.

Do you have computer? Computers have only 100 nanometers sized pieces. We can fit 1000 of them in wide of a strand of hair. The computers which we use daily life has 100.000.000 nanosized pieces. We use nanotechnology to develop these pieces. In the past computers were heavier than today and they are lighter now that nanotechnology is one of the reason for this. Old and new computers pictures are shown via projection.

Scientists are not know everything about nanotechnology and they are still studying about what can we do with nanotechnology and where can we use it. They are using very special tools and microscopes to study and search about nanotechnology and they must be very careful when using them. What for? Nanotechnology is brand new and it has lots of things that we should learn and discover. Would you like to study in nanotechnology and develop devices to make people's life easier? Students and teacher discuss about the question.

CHAPTER III

EVALUATION

1.What is coming to your mind when you heard nanotechnology word?

2.What is nanotechnology for?

LESSON 5

CHAPTER I

TIME: 40+40minutes

LESSON: NANOTECHNOLOGY IN OUR DAILY LIVES

CLASS: 5

CHAPTER II

GOALS: 1. To have an idea about usage of nanotechnology

2.To realize technology should use consciously

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, Question-Answer, Discussion

INSTRUCTION TOOLS: Projection, pictures

LESSON AREA: School, class

LEARNING-TEACHING PROCESS

Have you heard nanotechnological products or the products that its name contain nano word? Answers are listened. Nanotechnology are using from food to dress, from medicines to electronics nearly every field in daily life. Pictures of the products are shown via projection. Informations are given about these products, their usage in daily life and how they make our daily lives easier. Teacher and students are talked about the products.

Can we use nanotechnology in different areas? Students discussed about the question and determined their ideas. It is mentioned many of discoveries have not made in nanotechnology yet and we can use it in many larger fields. Thus, teacher helped students to understand the subject that they can make studies related this field in the

future.

Do you use computer? Can computers be harmful? In parallel of the answers it mentioned that technology can have benefits and harms at the same time and we should use it by realizing its harms and benefits. Can nanotechnology be harmful too? Students are promoted to talk about the questions. Then, it mentioned that nanoparticles can be harmful to human health, can disturb ecological balance and can reach some undesired place in body and be toxic accumulating in nature. It is mentioned some nanotechnological cleaning materials may damage lungs. It is explained we should use nanotechnology to aware of its harms and benefits just like other technologies. We should determine considering harms and benefits of it when we buy nanotechnological products. In parallel of this students are promoted to discussed about the question; is nanotechnology beneficial or harmful?

CHAPTER III

EVALUATION

1. Can you say a nanotechnological products?

2. Why should we use nanotechnology consciously?

APPENDIX B

BIOTECHNOLOGY LESSON PLANS

LESSON 1

CHAPTER I:

TIME: 40+40 minutes

LESSON: LET'S MAKE YOGHOURT

CLASS: 5

CHAPTER II:

GOALS: 1. Having an idea about the methods which scientists use and utilizing organisms for producing desired products

2.To give examples to application fields of biotechnology

LEARNING AND TEACHING METHODS AND TECHNIQUES: Lecture, question-answer, experiment, discussion

INSTRUCTION TOOLS: Milk, spoon, yoghourt

LESSON AREA: School, class

LEARNING-TEACHING PROCESS

How is yoghourt made? Have you ever seen your mother when she is making yoghourt? Students talk and discuss about the questions and it is explained to them yoghourt is made by microorganisms. We will learn how to make yoghourt in this lesson.

We are adding two spoons of yoghourt into the milk and thus, microorganisms

which become in yoghourt proliferate in warm milk and turn milk into yoghourt. Volunteer students are selected for fermenting the milk. Explaining to students, it must pass three/four hours in a warm environment for fermentation. Why are we putting milk in a warm environment and waiting? It is asked and listened the answers of the students. Also, it is explained that microscopic organisms which must proliferate to turn milk into yoghourt need a warm environment and time to provide this transformation. Fermented milk is covered with a cloth and put a warm place by students and it is said that the yoghourt will be ready after three/four hours.

After the needed time passed, the yoghourt is tasted by students and asked to them; how does milk turn into yoghourt. And then it is explained that scientists get produced some desired products to organisms like as we did. We call this technology "biotechnology". For example, Hepatitis B vaccine which we vaccinate in schools and more various vaccine are produced by microorganisms upon scientists requests. It is asked, is there anyone who has a diabetic and used insulin person in their family? Scientists get produced insulin hormone for diabetics to microorganisms abundant and cheaper way. Many more type drugs like vaccines and insulin are produced by microorganisms upon scientists' request.

How does dough fermented? The question is asked to students. The yeasts, which we add into the flour, are microorganisms. The microorganisms proliferate in flour with warm water and turn flour into dough fermenting just like yoghourt. Do you know how vinegar is made? Students talked about the question and then explained vinegar is produced by microorganisms, which we cannot see them with our bear eyes. Cheese, pickle and many more various foods are produced by microorganisms upon people's requests and these are very age-old biotechnological techniques.

CHAPTER III

EVALUATION

1. Can we make microorganisms produce the products we desire? How? Can you give an example?

2. Can you give examples about products which scientists lead microorganisms to produce?

LESSON 2

CHAPTER I:

Time: 40+40 minutes

LESSON: OVERVIEW OF BIOTECHNOLOGY

GRADE: 5

CHAPTER II:

GOALS: 1. To exemplify biotechnological applications

2. To realize that biotechnological applications for utilizing our daily lives and raising our life quality

TEACHING-LEARNING METHODS AND TECHNIQUES: Lecture, question-answer

INTRUCTIONAL TOOLS: Projection, video, e-newspaper

LESSON FIELD: School, class

TEACHING-LEARNING PROCESS

Have you ever heard about decreasing the amount of food in the world day by day? Every year nearly 670 thousand kids are going blind because of vitamin A deficiency. We have to produce more healthy and nutritious foods in our world which increasing its population and decreasing agricultural fields. Can we produce more healthy and nutritious foods? How can we achieve this?

Scientists ask for ways to bring solutions in our world which become more crowded day by day and struggle with food deficiency, water scarcity, pollution and various disease problems. Biotechnology is one of these ways. Have you heard the word before? Biotechnology means to get desired products using organisms and events related

to organisms. We fermented milk and turned milk into yoghourt in former lesson and we used the organisms which live in yoghourt and they turned milk into yoghourt. We can produce many more desired things by using organisms. For instance, animals which produced more meat and egg, potatoes which frying with less oil, plants which resistant against harmful warms and insects and drug plants when we eat them we can heal. Scientists produced many more of these. How can they do it?

What is gene? Have you heard the word before? After listening the answers the video watched; http://www.youtube.com/watch?v=4NegABEGTv4. Then, it is emphasised that genes gave the organisms all of their properties. For instance, shape of our ears, colour of our hair, shape and taste of a plant, etc. all of these coding with genes. What will happen if we change these codes? Can we produce more coarse-grained corn or a sheep which produced more meat?

Genes are existed in cells of organisms. To gain more nutritious animals and plants, their genes are manipulated with biotechnological applications. We can form more diseases resistant organisms by manipulating genes. Biotechnological applications have contributions to protect environment and consist healthier environment. For example, some bacteria which is formed by scientists can clean dirty waters without using chemical substances or drugs. Due to these bacteria we can clean the water without harming other organisms.

Did you hear GMO? GMO means genetically modified organism. Scientists achieved to make organisms healthier and more plentiful and more resistant plants and these plants are known as GMO products, by manipulating genetics. Related news are read from, http://www.bbc.co.uk/turkish/europe/story/2005/03/050328_golden_rice.shtml and then discussed with students.

GMO foods commonly made the market and are sold. Changing the genetics of the foods, they become more nutritious, more resistant against insects, viruses and bacteria and easily produced. What else can we do to manipulate genetics of organisms? Which organism would you choose if you wanted to manipulate genetics of an organism? Students talked about the questions.

CHAPTER III

EVALUATION

1. Can you give examples of products that producing with biotechnology?

2. Whar are the advantages of biotechnological applications?

LESSON 3

CHAPTER I:

Time: 40+40 minutes

LESSON: WHAT IS GMO?

SINIF: 5

CHAPTER II:

GOALS: 1. To exemplify biotechnological applications and their utilities.

2. To exemplify benefits and harms of GMOs.

TEACHING-LEARNING METHODS AND TECHNIQUES: Lecture, question-answer, discussion

INSTRUCTIONAL TOOLS: Projection, e-newspaper, video, photos

LESSON AREA: School, class

TEACHING-LEARNING PROCESS

Can we change shape, taste and content of the foods? Bringing to class GMO photos and talking with the student about photos. We mentioned GMOs in previous lesson. What comes to your mind when you hear the word GMO?

At present, there are more than 800 products which contain GMO. Scientists modified genetics of wheat, corn, potatoes, soya bean and many more products which we consume nearly every day with biotechnological applications. We can produce faster growing, resistant against insects and harmful organisms, more fruitful and more nutritious products by manipulating their genetics. Thus, farmers cannot need to use pesticide to kill the insects or protector drugs against diseases because these products resistant against insects, harmful organisms and diseases. To produce these products are

easier and cheaper. The video is watched from http://www.youtube.com/watch?v=6cvywk44o8Eandfeature=related and talked about it. At the same time, these products can provide nutritional needs of our bodies with smaller amount because they are more nutritious. http://www.bbc.co.uk/turkish/europe/story/2005/03/050328_golden_rice.shtml web news is recalled.

The world population is increasing and agricultural fields decreasing each passing day. Scientists think that these products can be a solution for starving which come near to us day by day. Moreover, these products are used in production of drug and vaccine. For instance, scientists inserted some genes into bacteria to provide them producing insulin hormones. Thus, diabetic persons can be easily treated. Similarly, by inserting some genes to bacteria they can produce Hepatitis B and more many vaccines.

Besides we can keep the genes of rare or endangered species. Thus, we can copy them again in laboratories. Students watched the video from http://www.youtube.com/watch?v=tbTw1NIxyzcandfeature=related and then talked about it.

In recent years, the discussions about potential harms of these products and applications are began by becoming spread and increasing biotechnological applications. For example, biotechnological products can cause cancer, allergy and disturb natural balance, change some beneficial properties of plants, damage organisms which living with plants and decrease diversity. Studies about benefits and harms of these products are still in progress. The scientists are continuing to studies and making discoveries which utilize our life. Nothing can be totally beneficial or harmful. We should use biotechnology carefully and conscious like any other technologies and considering the hazards of its.

CHAPTER III

EVALUATION

1. What is GMO?

2. Can you give an example about benefits and harms of GMO’s?

3. Does the right to use new technologies without investigating their risks and benefits?

LESSON 4

CHAPTER I

TIME: 40+40 minutes

LESSON: ETHICAL ISSUES ABOUT BIOTECHNOLOGY

SINIF :5

CHAPTER II:

GOAL: To have an idea about biotechnological applications which are applied on humans ethical or not

TEACHING-LEARNING METHODS AND TECHNIQUES: Lecture, question-answer, discussion

INSTRUCTIONAL TOOLS: Projection, photographs

LESSON AREA: School, class

TEACHING-LEARNING PROCESS

What was GMO? Answers are listened and remembered plants and animal samples with GMO. We mentioned about genetically modified plants and animals in previous lessons. Can we apply these applications on human? Human genes can be altered with biotechnological applications. Genes are information banks in our cells and they give us our vitality properties. Genes give all of vitality properties to organisms. Have you heard about genetic diseases? Students talked in this subject and the teacher informed them some diseases which come from genes transferring from our parents. For instance, if someone's both parents are diabetic, he/she will be diabetic most likely. Scientists found a way for pretending some genetic diseases before born by manipulating human genetics. Even parents can change their children's some properties like eye colour, intelligence,

length and many more properties. In your opinion is it true or false? Students are debated on the issue.

But in many of culture and religion human accepted as sacred. We could not completely know that if we altered to human genetics, they would encounter any problem in the future or not. Because of many similar reasons about doing biotechnological applications on humankind are a matter of debate. If these applications are used in a wrong way, it could cause damage human or other organisms?

Some countries allow these applications and some prohibited. But biotechnological applications which are done on plants, animals and other organisms are accepted by many countries. In many countries there are lots of debate on these issue and many people think human is sacred and choosing children's genes can cause lots of problems in the future. Because of this, having a child by altering their genes are prohibited in nearly all of the countries. In your opinion, is it beneficial of harmful? Students referred about the issue. Scientists are still studying on biotechnological applications to create cleaner and healthier environment and to utilize our daily lives.

Have you heard about cloning? Scientists achieved to generate clone organisms by copying genes of organisms and generating a copy organism which has donor's all vitality properties like twins. These clone organisms have same properties with donor and generate in laboratory environment.

Photographs of clone organisms are shown to students. Then, by using the photographs it is explained that clone animals carried completely same genes with their donor. That is to say, they have same properties with their donor like eye colour, length, shape of body, etc. briefly all of vitality properties. It is emphasised that these studies are being done all around the world. Scientists cloned mice, pigs, sheep, monkeys and they can clone humans too. Endanger animals can save by cloning and also by inserting some genes to clone animals some drugs and vaccines can be produced. In the future, clone animals can be used as organ donor for humans. As is known that cloning can practice in human too because it is practiced on sheep, mice, monkeys, etc. which become mammalian like human. However, there is no country which allows human cloning. In your opinion, is human cloning like other animals true or false? Do we need to legislate some laws related to the issue? Do you want to have a clone? Students debate on the

issue and are canalized multi-directional answers.

CHAPTER III

EVALUATION

1. What are the possible benefits and risks of having children altering their genetics?

2. In your opinion will be a discrimination between children which are born with manipulated genetics and normal children in the future?

3. If you were a scientist who interested in biotechnology, what would you like to produce by using biotechnology?