DESIGN AND IMPLEMENTATION OF A NANOSCIENCE & NANOTECHNOLOGY WORKSHOP: INVESTIGATING 11^{TH} GRADE STUDENTS' AWARENESS AND CONCEPTUAL UNDERSTANDING OF NANOSCIENCE & NANOTECHNOLOGY

by

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ABSTRACT

DESIGN AND IMPLEMENTATION OF A NANOSCIENCE & NANOTECHNOLOGY WORKSHOP: INVESTIGATING 11TH GRADE STUDENTS' AWARENESS AND CONCEPTUAL UNDERSTANDING OF NANOSCIENCE & NANOTECHNOLOGY

The purpose of this study was to develop a nanoscience and nanotechnology workshop (NNW) and determine its effectiveness by examining the change in students' awareness and conceptual understanding of nanoscience and nanotechnology related concepts. In this study, a mixed-method design was used. The quantitative part of the study included a pre-experimental design (pre-test and post-test design with no control group) and the qualitative part involved interviews, observations and artifacts. The participants for the research were 79 eleventh grade students from two private schools and a public school. Two different classrooms from the public school attended the NNW. Data regarding students' awareness of nanoscience and nanotechnology were collected through the Nanoscience & Nanotechnology Awareness Questionnaire (NNAQ). Seven items of NNAQ were adapted from Nanotechnology Awareness Instrument developed by Dyehouse *et al.* (2008). The other items of the NNAQ were added by the researcher. Nanoscience & Nanotechnology Conceptual Understanding Questionnaire (NNCUQ), Workshop Evaluation Questionnaire (NNWEQ) and semi-structured interviews were adapted from the instruments developed by Akaygun (2010a, b). In the study, the NNCUQ was used to measure 11th grade students' conceptual understanding of nanoscience and nanotechnology related concepts. The NNWEQ was used to assess student feedback and recommendations with regard to the workshop. In order to explore students' previous knowledge, understanding and expectations from the workshop, semi-structured interviews were conducted. Each one-to-one interview was audio recorded. Quantitative data were analyzed using the one-way ANOVA, paired samples t-test, independent samples t-test and chi-square tests. The interviews were transcribed and the student answers were coded. The results of the analysis indicated that attending the workshop increased the students' awareness and conceptual understanding of nanoscience and nanotechnology.

ÖZET

NANOBİLİM & NANOTEKNOLOJİ ATÖLYE ÇALIŞMASI TASARIMI ve UYGULANMASI: 11. SINIF ÖĞRENCİLERİNİN NANOBİLİM & NANOTEKNOLOJİ FARKINDALIĞININ VE KAVRAMSAL ANLAMALARININ İNCELENMESİ

Bu çalışmanın amacı, bir nanobilim ve nanoteknoloji atölyesi (NNW) geliştirmek ve öğrencilerin nanobilim ve nanoteknoloji hakkındaki farkındalık değişimini ve ayrıca nanobilim ve nanoteknoloji ile ilgili kavramlar üzerindeki kavramsal değişimlerinin incelenebileceği bir etkinlik uygulamaktır. Araştırmanın deseni nicel ve nitel yöntemlerin beraber kullanıldığı karma araştırma yöntemidir. Nicel ve nitel analizlerde; yarı deneysel araştırma grup modeli (kontrol grubu içermeyen, ön test-son test yöntemi) kullanılmıştır. Yetmiş dokuz katılımcı; iki farklı özel okul ve bir devlet okulunun iki farklı sınıfından gelen 11. sınıf öğrencileridir. Öğrencilerden, nanobilim ve nanoteknoloji farkındalığı ile ilgili veriler, Nanobilim ve Nanoteknoloji Farkındalık Anketi (NNAQ) ile toplanmıştır. NNAQ öğelerinden bazıları Dyehouse ve diğerleri (2008) tarafından geliştirilen Nanoteknoloji Farkındalık Anketi'nden alınmıştır. Anketteki bazı maddeler, araştırmacı tarafından yeni maddeler ile değiştirilmiştir. Nanobilim ve Nanoteknoloji Kavramsal Anlama Anketi (NNCUQ), Atölye Çalışması Değerlendirme Anketi (NNWEQ) ve yapılandırılmış görüşme soruları Akaygün'ün (2010a, b) araştırma çalışmasında kullanılan ölçeklerden adapte edilmiştir. NNCUQ, 11. sınıf öğrencilerinin nanobilim ve nanoteknoloji kavramlarını anlamalarını ölçmek için; NNWEQ ise öğrencilerin atölye çalışması hakkındaki istek ve önerilerini öğrenmek için uygulanmıştır. Öğrencilerin sahip oldukları bilgi, anlama ve atölye çalışması beklentilerini incelemek amacıyla, yarı-yapılandırılmış görüşmeler yapılmıştır. Her bir görüşmede ses kaydı alınmıştır. Görüşmeler deşifre edilerek kodlanmış ve analiz edilmiştir. Nicel veriler, tek yönlü ANOVA, eşleştirilmiş t-testi, bağımsız gruplar için t-testi ve ki-kare çıkarımsal istatistiki yöntemleri kullanılarak analiz edilmiştir. Analiz sonuçları, atölye çalışmasına katılan öğrencilerin farkındalık ve nanobilim ve nanoteknoloji kavramsal anlamalarında artış olduğunu göstermiştir.

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LIST OF SYMBOLS

N	Number
nm	Nanometer

LIST OF ACRONYMS / ABBREVIATIONS

AFM	Atomic Force Microscope
CNSI	California Nanosystems Institute
EU	European Union
MRSEC	Materials Research Science and Engineering Center
NASA	National Aeronautics and Space Administration
NCLT	National Center for Learning and Teaching Nanoscale Science and Engineering
NISE	Nanoscale Informal Science Education
NNAQ	The Nanoscience & Nanotechnology Awareness Questionnaire
NNCUQ	Nanoscience & Nanotechnology Conceptual Understanding Questionnaire
NNI	National Nanotechnology Initiative
NNW	Nanoscience and Nanotechnology Workshop
NNWEQ	Nanoscience & Nanotechnology Workshop Evaluation Questionnaire
NSEC	Nanoscale Science and Engineering Center
NSF	National Science Foundation
NTSE	Nanotechnology for Science Education

Pr1	Private School 1
Pr2	Private School 2
Pu1	Public School 1
Pu2	Public School 2
SEM	Scanning Electron Microscope
STEM	Science, Technology, Engineering and Mathematics
STM	Scanning Tunnelling Microscope
PAST	Personal Awareness of Science and Technology
PUS	Public Understanding in Science
TUBITAK	The Scientific and Technological Council of Turkey
UNAM	Institute of Material Science and Technology
US	United States of America

1. INTRODUCTION

The general understanding of science education has changed in the twenty first century. Osborne (2007) states that the twenty-first century science education requires scientific content, scientific approach to enquiry, and science is viewed as social practices of the community, whereas the role of science is to resolve the contemporary dilemmas that society faces.

The new vision of science education necessitates various skills for students in the twenty first century. Being scientifically literate is one of the necessary skills for all young people no matter what their career plans or aptitudes are (Millar and Osborne, 1998). In other words, scientific literacy is the major goal of science education so as to advance individual development within the context of science and technology (Bybee, 1997). In Turkey, within the vision of the new primary school science and technology curriculum, increasing the quality of science and technology courses at schools is the key for developing scientifically literate citizens (Talim Terbiye Kurulu Baskanligi, 2005).

As science and technology advance, raising scientifically literate individuals who have an understanding of nature of science and who are aware of the new discoveries and developments in science and technology is a challenging process. According to the Nuffield Foundation's "Beyond 2000: Science Education for the Future Report" (1998), compulsory science education curriculum should be designed with regard to the difference between the needs of a future scientist and the needs of a future citizen. Moreover, twenty-first century science curriculum focuses not only on having scientifically literate citizens who study the basic concepts of science but also on creating opportunities for future scientists so that they have a chance to reach more specialist science degree subjects and develop their practices. In this respect, science and technology curriculum should integrate new scientific and technological developments.

Nanoscience and nanotechnology or nanoscale science could be one of the subjects to be considered in the science education curriculum, as they are new scientific and technological developments. In the study of Sweeney *et al.* (2003), it is implied that nanotechnology is expected to impact all the aspects of human experience, which is why scientific literacy regarding nanotechnology becomes an issue of considerable importance. In addition, Schank *et al.* (2007) state that nanoscale science is a part of modern science and it requires a population with a high degree of scientific literacy. They have identified the lack of nanoscience education in middle school and high school programmes in the United States of America (US) and concluded that nanoscience education could increase students' scientific literacy as well as prepare them for their further studies. This realization has created a national concern in the US towards nanoscience and nanotechnology education, which aims to increase the number of workforce as well as the intellectual capacity of citizens. Roco (2003a) estimated that two million people with knowledge of nanoscience would be needed in different professions by the year of 2015.

Recently, nanoscience and nanotechnology have taken the attention of many countries including the United States of America and European countries as emerging areas in science and technology. For instance, European Commission (2005) reported a nanotechnologies and nanosciences action plan for Europe 2005 to 2009. In this plan, they aimed to promote growth and jobs in the field of nanotechnology through interdisciplinary education and training. In Germany, the German Federal Ministry of Education developed a national strategy in 2006. The purpose of this strategy was to promote education, research and innovation in nanotechnology. Similarly, according to Vision 2023, developed within the scope of the National Technology Foresight Program by the Scientific and Technological Research Council of Turkey (TUBITAK), nanotechnology has been considered as one of the strategic technology fields. Beyhan and Pamukcu (2011) state that in June 2010, 337 academic projects related to nanoscience and nanotechnologies were funded by TUBITAK. 176 of these projects have already been completed.

Different approaches and educational implications have been developed and supported in many countries with regard to the development of human capacity in nanoscience and nanotechnology. For example, in the United States, there are many projects funded to develop curriculum materials, short and long term nanotechnology and nanoscience related projects, workshops, summer schools as well as informal nanotechnology activities such as museum exhibits, demonstrations, multimedia in science centers and museums. All these initiatives have been carried out to set national standards and benchmarks. A few examples of these projects from the United States are the National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT), the Nanoscale Informal Science Education (NISE) and the National Nanotechnology Initiative (NNI). Other countries also developed similar projects. For instance, Swiss National Programme TOPNano21 is similar to NNI in the US. As Germany has been the most active European country in nanotechnology, the federal government has funded initiatives such as Nanonet Networks that bring public research institutes and industries together (Schulte, 2005). All these initiatives had a common mission to develop scientifically literate individuals as workforce in the future (Schank *et al.,* 2007).

According to Vision 2023 Report of Turkey, nanotechnology is one of the strategic technologic fields in which there have been attempts to launch nanoscience and nanotechnology initiatives in Turkey (Saritas *et al.*, 2007). Beyhan and Pamukcu (2011) referred to the archives of the Turkish Official Journal and found out that there were six nanoscience and nanotechnology research centers and institutes established after 2004. Gebze Institute of Technology, established as an international science and technology producer in 2004, aims to educate innovative and broad-minded researchers as well as to support Turkish industry to gain a strong position in the competitive global arena. Institute of Material Science and Nanotechnology (UNAM), founded by Bilkent University in Ankara, develops projects based on nanoscience technology to strengthen the competitiveness of Turkish products in international markets and offers training courses for technical personnel, researchers and experts through a multidisciplinary graduate programme. They also take part in the preparation of TV and radio programs, scientific magazines and newspapers for public education in nanoscience and nanotechnology. In 2008, Nanotechnology and Biomaterials Application and Research Center was established at Marmara University. In 2009, The Nanotechnology Research and Application Center was established at Canakkale Onsekiz Mart University and The Nanomedicine and Advanced Technologies Research and Application Center was founded at Gazi Univesity in Ankara. In 2010, another Nanotechnology Research and Application Center was established in Istanbul. It was founded by Sabancı University. This center is the first interdisciplinary nanotechnology center in Turkey. It aims to develop projects in the fields of physics, electronics, mechatronics, materials science, chemistry, and biology.

In addition, many universities in Turkey have established their own nanotechnology laboratories. Gazi University and Hacettepe University in Ankara and the Institute of Technology in Izmir are a few examples only. There are also universities, such as Middle East Technical University in Ankara and Bogazici University in Istanbul, which provide use of their laboratory facilities not only to their members but also to researchers from other universities and firms working in the nanotechnology field.

The number of master and PhD programs provided by Turkish universities in the field of nanoscience and nanotechnology has increased in recent years (Saritas *et al.,* 2007). The universities that provide graduate programs in this field are Bilkent University, Middle East Technical University, Hacettepe University, Anadolu University and Istanbul Technical University. Nanotechnology has also been integrated into the curriculum of Physics and Chemistry graduate programs (Beyhan and Pamukcu, 2011).

As well as graduate students, younger students, ranging from primary to secondary school, have also been involved in nanoscience and nanotechnology projects. There are several European Union projects that support students at different levels of education. *NanoYou*, in which some primary and secondary schools in Turkey have been involved, is one of these projects. This project was funded by the European Commission's Seventh Framework Programme that aimed to increase young people’s basic understanding of nanotechnologies and to engage in the dialogue about its ethical, legal and social aspects. *NanoYou*'s target audiences were young people aged between 11-25 years old. At least 400 schools were meant to participate, with programmes reaching more than 25,000 students. The Web Portal also served as a tool for information dissemination. A range of virtual activities were available, as well as a communication space with virtual forums where students could engage in different dialogues. Moreover, a strong network allowed different institutions and schools to share experiences and resources. To become a member of this project, schools needed to register online as *NanoYou* schools. After the registration process, some schools were selected as pilot schools and science teachers started to teach nanotechnology in their classrooms with videos, animations, games, virtual dialogues and virtual experiments based on current research provided on the project’s website. One private primary school from Afyonkarahisar was representing Turkey as the pilot *NanoYou* School. The Science Center in Istanbul which was established in 1998 by Turkey Science

Centers Foundation (TSCF) also participated in various European Union (EU) projects, as announced on their website. They carried out simultaneous projects with leading Science Centers & Museums in Europe. One project that TSCF has been involved in is called *Time for Nano*. The partners of *Time for Nano Project* were science centers and museums in nine European countries, namely Italy, Belgium, Slovenia, Portugal, France, Poland, Finland, United Kingdom and Germany. This was the very first project with an aim to introduce nanoscience and nanotechnology to young generation in Turkey. It included “Nano Days”, interactive experiments with “Nanokit”, contests and training courses for teachers. Nano Technology for Science Education (NTSE) is another nanoscience project funded by the European Commission, one of the participants of which is a private education institution from Turkey. This project is a Transversal KA3 ICT project that aims to use ICT as a tool to make the learning of science subjects more attractive and accessible. There were students aged between 13 and 18 from general and vocational schools, science teachers and college and university students involved in the project. Participant countries were Turkey, Italy, Bulgaria, Greece and Romania. The project aimed to establish a Virtual Lab, as an experimental virtual aid to science learning.

There was one example to an individual project called “Türk Gençliği Nanoteknoloji Kulübü” developed by a researcher, who has been working at UNAM on the subject of LED. This project has also been supported by the Turkish Board of Education. The aim of the project was to introduce nanotechnology to students starting with kinder garden through high school (Ak, 2009).

In addition to these nanoscience and nanotechnology education attempts for students in Turkey, there is still need for more education opportunities. With regard to what nanotechnology initiatives have done in the US and the European countries such as Germany, various projects can be developed in Turkey. These projects can be about developing curriculum materials, long term nanotechnology and nanoscience related projects, short and long term programs such as workshops, summer schools, informal nanotechnology activities such as museum exhibits, demonstrations, multimedia in science centers and museums.

This study was an attempt to develop a one-day nanoscience and nanotechnology workshop (NNW) and measure the change in 11th grade students' awareness and conceptual understanding of nanoscience and nanotechnology. For the purposes of this study, a nanoscience and nanotechnology workshop was held at Bogazici University in Istanbul. In particular, this study attempted to address how a nanoscience and nanotechnology workshop could be developed and implemented in and out of school environment, bringing school teachers, students, prospective teachers, academics and researchers from the university together to support nanoscience and nanotechnology education for 11th grade students.

2. LITERATURE REVIEW

The purpose of this literature review is to examine the studies, in relation to the issue of nanoscience and nanotechnology education, that have been published in the field of science education.

The body of literature on nanoscience and nanotechnology education has been discussed and synthesized under different chapters. The first chapter, “What are Nanoscience and Nanotechnology?” presents a brief overview of how nanoscience and nanotechnology are defined. The second chapter “Nanoscience and Nanotechnology Education” deals with nanoscience and nanotechnology education as emerging areas of science education worldwide. Chapter three, “Nanoscience and Nanotechnology Education in Secondary Schools” discusses and lists various examples of nanoscience and nanotechnology education in secondary schools in different countries. The fourth chapter entitled “Students’ Understanding of Nanoscience” deals with students’ conceptual understanding of nanoscience and nanotechnology in relation to the subjects of “Size and Scale”, “Structure of Matter”, “Dominant Forces”, “Tools and Instrumentation” and “Nanoscience and Society”. The following chapter “Students’ Awareness of Science and Technology” focuses on nanoscience and nanotechnology. Students’ perception of risks and benefits of nanotechnology are also discussed in this chapter.

2.1. What are Nanoscience and Nanotechnology?

The Japanese scientist Norio Taniguchi from Tokyo University of Science was the first to use the term "nanotechnology" in 1974. He defined “nanotechnology” as consisting of processing, separation, consolidation, and deformation of materials by one atom or one molecule (Kazlev, 2003).

There are many definitions emphasizing the scale aspect of nano (Whitesides and Love, 2007). These definitions mainly point out the fact that at the nanometric scale properties differ significantly from macroscopic scale properties. For example, the National Nanotechnology Initiative (NNI) from the US states that understanding and control of matter at the dimensions of 1 to 100 nanometers enable novel applications (National Nanotechnology Initiative, 2006). These novel applications are mentioned as encompassing nanoscale science, engineering and technology, imagining, measuring, modeling and manipulating matter at the length scale of 1 to 100 nanometers (The National Nanotechnology Initiative-Strategic Plan, 2007). This definition is similar to the definitions by other authors (Stevens *et al.,* 2009; Lu, 2009; Cacciatore *et al.,* 2011). Another definition that emphasizes the nano scale aspect of nanotechnology defines nanotechnology as working at the atomic, molecular levels, in the length scale of approximately 1 – 100 nm range, in order to understand and create materials, devices and systems with fundamentally new properties and functions because of their small structure.

Another common point in the definitions is the emphasis on the interdisciplinary nature of nanoscience and nanotechnologies (Hutchinson, 2007; Porter and Youtie, 2009). In the article of Bava *et al.* (2005) nanotechnology is defined as an umbrella term used to define the products and processes at the nano scale that result from the convergence of the physical, chemical and the life sciences. Lastly, the other common point in the definitions is that nanotechnology is discussed with its applications in different fields such as electronics, medicine, biotechnology, agriculture, and chemical/pharmaceuticals and materials (Roco, 2004; Wong *et al.,* 2007). Nanotechnology is also considered as a part of different technologies such as biotechnology, information and cognition (Roco and Bainbridge, 2002). According to Whitesides and Love (2007) nanoscience and nanotechnology are described as the combination of a number of areas such as biology, computer science, chemistry, material science, electrical engineering, and solid-state physics.

2.2. Nanoscience and Nanotechnology Education

Nanoscience and nanotechnology education are the emerging areas of science education worldwide. Chank (2006) points out that ‘nano’ as a driving force for education and nanoscience education can fire the imagination of young people and increase their interest in science and technology. Blonder and Dinur (2011) state that the subject of nanotechnology has the potential to be appealing for high school students as a modern research subject that has many potential applications. According to Schank *et al.* (2010)

meaningful and relevant experiences in nanoscience topics should be provided to high school students, so that the number of students interested in nanoscience and nanotechnology increases, which will eventually lead these students to nanoscience related careers.

Designing nanoscale science education was noted as challenging since direct experience with nanotechnology outside the classroom almost does not exist (Gardner *et al.*, 2010). In this regard, there are many attempts to deal with this challenge. Scientists, educators and curriculum developers work on and try to develop learning materials and create learning environments both in school and outside of the school (Schank *et al.,* 2007).

The pioneer countries in science and technology, such as the United States, pay great attention to nanoscience and nanotechnology education. As Roco (2003b), the senior advisor for Nanotechnology at the National Science Foundation (NSF), stated the need for a new generation of skilled workers in nanotechnology. He argued that nanotechnology education should become a priority to meet this need. Roco also estimated that by 2015, there would be a need for about 2 million skilled workers. Similarly, Greenberg (2009) revealed that the aim of the National Nanotechnology Initiative (NNI) is to "sustain and develop educational resources", "give education and training to a new generation, who will be the skilled workforce in close future".

To realize those goals, many nanoscience and nanotechnology education research projects, programs and activities are still being developed by scientists, academics and researchers from different fields of science and technology. These great ranges of educational resources are developed to take considerable amount of funding and support from foundations and initiatives such as the National Science Foundation (NSF) and National Nanotechnology Initiative (NNI) (Greenberg, 2009). Indeed, the Scientific and Technological Research Council of Turkey (TUBITAK), gives funding to such projects related to nanoscience and nanotechnology (Beyhan and Pamukcu, 2011).

2.3. Nanoscience and Nanotechnology Education in Secondary Schools

Introducing nanoscience and nanotechnology in secondary schools is an opportunity to reform the US Science, Technology, Engineering and Mathematics (STEM) Education (Hingant and Albe, 2010). The reform is needed in order to create an opportunity for students to reach the level of 'nanoscientific literacy' so that sufficient workforce be trained for the future (Greenberg, 2009; Schank *et al.,* 2007).

Stevens *et al.* (2009), the authors, of the book 'The Big Ideas of Nanoscale Science and Engineering: A Guidebook for Secondary Teachers' suggested nine big ideas to create and improve general nanoscientific literacy. The authors of the book, who are a group of scientists, educators, researchers, and curriculum developers, provided a thorough discussion of nine "*Big Ideas*" of nanoscale science and engineering, namely the size and scale, the properties of matter, the particulate nature of matter, tools, modeling, dominant forces, technology, society, and self assembly. In addition, the core concepts that match with standards were set forth to be helpful for teachers to integrate nanoscience concepts into their lessons. These concepts were also regarded as an opportunity to revise the content in the STEM curricula (Albe, 2010).

There were various numbers of nanoscience and nanotechnology education projects, programs and modules that were designed to integrate 'nano' into the secondary schools' curricula. One example was a designed 'Nanoscience and Nanotechnology Introductory Module' for high school students. This module was designed as an introductory module in which students were guided in a series of inquiry-based and hands-on activities. The purpose of the projects was to engage students in nanoscience related classroom activities as well as motivate them and promote their interest in science. The goal was to teach the significance of the surface-area-to-volume ratio, as objects get very small. Students investigated how the physical form of a material can influence the degree to which an object interacts with its environment. They worked on math tools needed to express very small quantities, powers of 10 and scaling. The shape and size effects on surface areas and volumes were also explored. It was concluded that this module facilitated the engineering skills (Maynard *et al.,* 2006).

NanoSense project (2004-2008) was another project from the US that aimed to develop, test and revise four curriculum units that could be integrated into high school science classrooms. The scientists and educators who created this project aimed to prepare, guide and engage teachers to teach nanoscience through activities along with the units and materials of the units they developed. The units were named as introduction to nanoscience, clear (nanoparticulate) Sunscreen, Clean (nanosolar) Energy, Fine (nano) Filters. Based on the implementation of these units into six different high school classroom programmes, an evaluation of the curriculum was conducted and its results were reported. The results of the study revealed that students made significant gains in understanding the nano-related concepts, but many nano-related concepts were found difficult for students who often build on basic scientific ideas they are not yet fluent in. It was suggested that teaching these basic scientific ideas immediately prior to the nanoscience related topic would be a useful strategy for success (Schank *et al.,* 2010).

The NanoLeap project, which was supported by the National Science Foundation (NSF), was a project designed by McREL education research laboratory. Their goal was to give opportunities to students to explore where nanoscale science, technology, engineering, and mathematics concepts could fit into the high school curriculum. They also worked on the development of useful teaching materials in the areas of nanoscale science and technology. The project outcomes showed that the project supported inquiry-based learning, increase levels of interest and engagement in learning science, increase understanding of core concepts, nanoscale science, technology, engineering, mathematics, concepts and applications. The project developed its instructional materials based on the "Big Ideas" reached by Stevens *et al.* (2009).

Summer courses are other learning environments for nanotechnology. For instance, the department of Chemistry in Columbia University in 2008 offered a course on material science and nanotechnology for high school students. The course was designed by instructors, staff of assistants, research scientists and technology experts from Columbia University National Science Foundation Materials Research Science and Engineering Center (MRSEC) and Nanoscale Science and Engineering Center (NSEC), as well as from the industry and national laboratories. In this course, students experienced hands-on introduction to materials science, engineering and technology. The course program included nanoscale properties of large and small molecules, nanoscale materials and devices.

Nanotechnology education also means workshops for high school students. A two-day workshop, “the California NanoSystems Institute (CNSI) Nanoscience Lab”, was designed and planned to take place in summer 2012. National Science Foundation (NSF) and National Aeronautics & Space Administration (NASA) funded the workshop. It was an exclusive summer workshop for high school students who were interested in advanced science and technology. The program was designed by the UCLA graduate and postdoctoral researchers. The workshop aimed to give opportunities to students so as to explore the questions similar to those currently investigated by the scientific community. The program was introduced with hands-on experiments that combine vigorous scientific methodologies and techniques with projects that are both fun and exciting. The other activities included lectures, discussions, scientific instrumentation trainings, and science career mentorship.

Beside the US, there are also some initiatives in Europe that develop projects and materials to support science teachers to introduce nanotechnology to their students (Mallman, 2008). For instance, the GermanSaarlab Initiative offered laboratory days for whole school classes whereas German Truck offers exhibitions about nanotechnology. NanoBioNet from Germany, which is a non-profit association, was founded to provide experimental kit to teach students about nanotechnology. They also introduced themselves as one of the largest German networks in nanotechnology. The University of Cambridge offers school visits, interactive lectures, seminars and workshops (Mallman, 2008).

There are also some nanotechnology related activities for high school students in Turkey. Istanbul University offered a ‘Nanotechnology Summer School’ for high school students in 2011. In this three-week’s program, students attended lectures, which covered a range of topics from the concept of atom to nanotechnology. Students also conducted some experiments related to important physics concepts such as atom, electron, and wave like property of matter, quantum physics, electron diffraction, photoelectrons, x-ray and its properties, lasers, formation of molecules, amorphous solid structures. Another seminar was organized for high school students by Eskisehir Municipality and the Turkey Science

Centers Foundation with the support of a European Union Projects called "*The Time for Nano Project"*. The aim of the project was engaging the general public, with a special attention to young people. It was about the benefits and risks related to nanoscale research, engineering and technology, with the help of specific informal education products. Approximately 200 students attended this seminar. During the seminar, which was given by nanotechnology educators from the Science Center (Bilim Merkezi), first brief information about nanotechnology was introduced to students to teach them more about nanotechnology. Then, nanotechnology related videos, demonstrations and activities were introduced to students. These seminars were also held in different cities in Turkey, which was announced on the official website of the *Time for Nano project*. Such events are called "Nanodays", generally consisting of demonstrations, experiments, games, meetings and discussions about nanotechnology. Between the years of 2009-2010 several 'Nanodays' were organized in different cities such as Istanbul, Gaziantep, Izmir, Bursa, Eskisehir and Manisa.

One public high school was nominated as one of the pilot schools in *NanoYou* project, a youth project funded by the European Comission. In *NanoYou,* on the pilot school's blog, the project coordinator stated that "NanoYou gave materials, project ideas, organized contests and offer up- to- date developments about nanotechnology". Students did not only take what was taught them for granted but they questioned, made experiments, worked and explored together and discussed whether this technology has ethical basis and how it would affect the environment and people in the future. Cultural exchange helped share their ideas and broaden their understanding of nanotechnology.

"Nanochannels" is another funded project by the European Commission. The members of this project are two high schools from Turkey. The Nanochannels project was introduced as a unique public experiment of democratic dialogue in action about the new industrial revolution that could change the face of medicine, energy production and water purification, electronics, materials and security. Nanotechnology was introduced as a subject to debate that takes place about its potential benefits and risks. On the official website of the project, students posted materials such as videos, interviews, experiments, news could be reached. One example that was posted by a private high school from Turkey

was about an experiment about absorption of sunglasses and sunscreens, which was conducted in Istanbul Technical University on March 2012.

With the collaboration of Yeditepe University and Private Kaşgarlı Mahmut Science School in April 2012, one seminar and workshop about nanotechnology were held. The program included the introduction to nanotechnology, applications of nanotechnology, integration of nanotechnology to high school curriculum, workshop, and introduction of nanotechnology products. The aim of the organization was to raise awareness, share update news about nanotechnology as well as the integration of nanotechnology into the high school curriculum.

Another university related nanotechnology education activity will be held at Sabancı University in 2012. The two-week programs will have two terms. High school students will have the opportunity to select courses entitled 'Quantum Mechanics and Nanoscience' and'Molecular Biology, Genetics and Nanomedicine'.

The literature review showed that there are numerous nanoscience and nanotechnology education projects, programs and modules that are designed to integrate 'nano' into the secondary school curriculum in many developed countries, especially in the US. In the study of Ak (2009), it was also suggested that similar studies should be done in Turkey and new projects should be carried out to make use of nanotechnology education.

2.4. Students' Understanding of Nanoscience

As the nanoscale is accessible with the emerging new tools and instruments, understanding nanoscience becomes necessary. Students' understanding and acceptance of emergent technologies like nanotechnology, is also an important component of scientific literacy (Gardner *et al.,* 2010).

Since nanoscience has an interdisciplinary nature, this could create an opportunity for students to develop a deeper understanding of core concepts and principles, which they would also be able to associate with the learning goals of the curricula. In other words, there would be some common concepts between traditional curricula and nanoscience. It was also suggested to consider nanoscience not as a separate topic but as integrated into the traditional curriculum. Thereby, nanoscience concepts would match with concepts related to disciplines such as mathematics and science. Concepts related to "size and scale" mentioned with its connection to mathematics, science, history and geography. It was stated that to communicate the size of things in any subject area, standart measurement units and numerical values are required (Stevens *et al.,* 2009).

Hutchinson *et al.,* (2007) also noticed that nanoscience and nanotechnology concepts were not usually addressed significantly in the traditional science curricula, but students might show an interest in these phenomena. Based on this idea, Hutchinson *et al.,* (2007) first identified nanoscale related activities that motivated learners to explore and learn nanoscience topics. Then they investigated the types of topics used to encourage students to learn nanoscience concepts. They also reported students' suggestions upon nanoscience concepts that would bring interest and excitement to science classes. This study showed that students showed more interest in learning about nanoscience when the activities and questions were related to students' interests.

Since students' interest toward science is a key factor in their science achievements, Hutchinson (2007) pointed out that nano related concepts could be suggested as a means to increase students' interest in science. The reasons for this suggestion are the integrated nature of nanoscience and its popularity among society. According to students' views gathered in the study, it was suggested to consider some characteristics of nanoscience concepts before introducing them to students. These characteristics were general curiosity, personal interests, relation to everyday life, and hands-on experimentation.

While the Turkish Secondary Education system has been going through some revisions in order to improve science education, there is still a big need to include scientific ideas resulting from the emerging fields of science such as nanoscience, which is interdisciplinary in nature. This interdisciplinary nature shows that ideas from chemistry, physics, and biology are important. Considering the Turkish traditional secondary school curriculum under these three main science subjects, and also some of the "Big Ideas" of nanoscience stated by National Center for Learning and Teaching Nanoscale Science and Engineering (NCLT) could be included as core concepts in an introductory workshop

(Stevens *et al.,* 2009). These Big Ideas, which have been regarded as appropriate for grade 7-12, were size and scale, properties of matter, particulate nature of matter, tools, modeling, dominant forces, technology and society, and self-assembly.

In the NNW, not all the "Big Ideas" were covered. The "Big Ideas" that were included in the NNW were "size and scale", "structure of matter", "dominant forces", "tools and instrumentation", and "technology and society". These ideas were selected according to the prerequisite science knowledge of grade 11 students. In this section, only these "Big Ideas" will be explained.

2.4.1. Size and Scale

Size and scale was one of the "Big Ideas", which were identified in Nanoscience Learning Goal Workshop organized by National Center for Learning and Teaching Nanoscale Science and Engineering (NCLT) in 2006. According to Stevens *et al.*, (2009) size is defined as the actual extent, bulk or amount of something. Scale is defined as to link the size of an object to a numerical representation of that size conventionally defined units such as meters, grams, gallons and light years. Authors also added that these concepts underlie all the other big ideas of nanoscience. It was revealed that size defines the nanoscale, and scale gives explanation about the behavior of matter. As size and scale changes, the properties of matter change. Stevens *et al.*, (2009) gave example of the special properties that matter exhibits on the nanoscale result from the effect of size on the surface area to volume ratio. They explained that in chemistry this relates to the number of atoms on the surface relative to that of the bulk material.

Some of the studies put emphasis on students' nanoscale science and their related conceptions. One of the studies about understanding the concepts of size and scale was done by Delgado (2009) who was concerned with what students already know and how they think about it. The purpose of the study was to develop a learning progression for size and scale, so as to be used to guide the development of a more effective curriculum, instruction and assessment. Delgado (2009) conducted a cross-sectional study with 101 middle school students among undergraduate students. In his study, the researcher built a learning progression for size and scale that focused on four different aspects. These aspects were ordering by size, grouping by size and relative scale (how many times one object is bigger than the other) and absolute scale. The researcher stated that these four aspects of size and scale could make it easier to retain information about the size of objects by helping students contextualize and store it in several ways. The results of the study showed that learning measurement units smaller than millimeters including micrometers, nanometers were found to be powerful tools for student learning about submacroscopic world.

Stevens *et al.*, (2009) agreed that nanoscience concepts, in other words “Big Ideas”, should be integrated into the curriculum. Furthermore, they pointed out that these concepts were already in the science curriculum. According to Ak (2009), in the current Turkish curriculum, the term “nano” is mentioned in 2008-2009 grade 9 biology books in the “Cell” unit. It was mentioned that the size of cell membrane was given as 12 nm, the ribosome organelles in 20 nm in prokaryotes and 30 nm in eukaryotes. It was also stated that in the Appendix of that biology book, the international units system (SI) table included information about “nano”. Ak (2009) suggested that this situation could be considered as an indicator to introduce students to the nanometer scale. In the grade 9 chemistry curriculum, which was published in 2007, the section called *“Kimya dersi öğretim programının gerekçeleri- Reasons for chemisty curriculum”* informs that:

“Gelişen teknolojinin, gündelik hayatta kullanıma sunduğu nanoteknoloji ve mikro elektronik ürünlerinin, kimyayı ilgilendiren yönleri ile programda yer alması gereği doğmuştur- A requirement arose regarding nanotechnology daily life uses with the chemisty aspects”.

Although these ideas mentioned in the chemistry curriculum of 2007, nanotechnology was not covered in any chemistry units in grade 9 books. In the 10 grade 10 chemistry curriculum of 2011, the same explanation mentioned above was included in the section called *“Kimya dersi öğretim programının gerekçeleri- Reasons for chemisty curriculum”*. This time, in the unit called “Mixtures” an example given about nanometer was as follows:

"Homojenliğin anlamı, dağılan maddenin tanecik boyutu, mikroskopların büyütme oranları ve görsel duyunun boyut sınırları temelinde tartışılır. Böylece çözeltilerin, "boyutu 10 nanometreden daha küçük olacak şekilde dağılmış maddelerin oluşturduğu karışım" şeklindeki tanımı anlamlandırılır. - Homogeneity means that the particle size of dispersed substances and enlarging ratio of microscopes are discussed on the basis of growth rates and size limits of visual sensation. Thus, solutions can be defined as the mixture formed by the dispersed substance the size of which is less than 10 nanometres.

"Nano" as a scale, also took place in the chemistry curriculum of 2011. In the introductory part of the "mixtures" unit, one nanometer was defined as the upper limit of the molecular size to show the microscopes' zooming ability.

2.4.2. Structure of Matter

Although understanding the structure and behavior of matter in bulk and atomic levels is relatively well-developed, there is limited knowledge about how matter behaves differently in bulk and atomic levels (Stevens *et al.,* 2009). The authors believed that interesting properties at the nanoscale can be related to the specific properties of constituent atoms. To set an example to these different forms of carbon, "allotropes" were introduced. Diamond, graphite and charcoal were mentioned as most common forms of pure carbon. These different forms of carbon were included in grade 9 chemisty curriculum of 2011 in the unit of "compounds". These allotropes were referred to as examples to covalent network structures. Bucky-ball as another allotrope was given as example by Stevens *et al*. (2009). Bucky-ball was defined as hollow sphere-shaped molecules commonly consisting of 60 carbon atoms. The other example to allotropes included carbon nanotubes. Carbon nanotubes were defined as extended structures that have a diameter of only few nanometers. They have properties of having high electrical conductivity, having resistance to heat, being the strongest and stiffest material known. These allotrope examples were also covered in the lesson units of *Nanosense project,* which were "Introduction to Nanoscience" and "Scale of Objects". Buckyballs and carbon nanotube might also be introduced to 9^{th} grade chemistry students as another example of covalent network structures. Stevens *et al*. (2009) stated that the basic physics of atoms and molecules is the foundation of all science. Emphasizing the nanoscale related concepts such as buckyballs and carbon nanotubes would be beneficial for students as they study biology, physics, chemistry and earth science. Another example related to science curriculum was “proteins”, which are also nanoscale objects. In the 9th grade Turkish chemistry curriculum, the units of “compounds” referring to covalent stuructures and organic compounds could also include buckyballs, carbon nanotubes and proteins as examples of nanoscale objects.

The authors Stevens *et al*. (2009) also emphasized that understanding the *structure of matter* is critical to building understanding of many aspect of nanoscience. Based on this, in the 10th grade Turkish chemistry curriculum, the unit of “Atomic structures” and the unit of “Interactions between different species” could also mention nanoscale materials which are also made of atoms, molecules or other nanoscale objects.

2.4.3. Dominant Forces

Since nanotechnology utilizes the unique properties of matter on the nanoscale to design and create new nanoscale structures, it is important to understand how they are held together.

It was explained that small objects such as atoms, molecules and nano particles interact in a variety of ways; Van der Waals forces are one type of electrical forces which are responsible for intermolecular interactions between atoms, molecules and nanostructures (Stevens *et al.,* 2009). In other words, understanding the electrical forces that are responsible for intermolecular interactions, which lead to the interaction between atoms, molecules and nanostructures, are essential to understand nanotechnology.

The National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT) supported nanoscience and nanotechnology projects to integrate nanoscience into the curriculum. Among those lessons developed in 2007, five lessons out of twelve were on the topic of intermolecular forces. The evaluation of the lesson development project also showed that teachers are more likely to develop a lesson related to the topic from the curricula (Greenberg, 2009).

The projects such as Nanosense and NanoLeap, which were mentioned in section 2.3, also used the concept of intermolecular forces in their teaching units. Nanoleap project considered the concept of *intermolecular forces* as one of the core concepts from the "Big Ideas" in nanoscience.

Stevens *et al.* (2009) pointed out that connecting the "chemical interactions" subject that includes ionic, covalent, dipole- dipole, London dispersion/Van der Waals with idea of "electrical forces" will facilitate student understanding of the same forces involved in interactions of both atomic and nano scale.

In the 10^{th} grade chemistry curriculum, the unit of "Interactions between different species" can be linked to "electrical forces" so that students can relate a curriculum subject to an emerging science field, which is nanotechnology. The understanding of "electrical forces" idea would enable them to understand how nanoscale structures are designed and built. In other words, understanding "electrical forces" is essential to create nanoscale assemblies and materials.

2.4.4. Tools and Instrumentation

Development of tools led to discover and increase the level of understanding of matter. Stevens *et al.* (2009) stated that there have been advances in microscopy in the 20^{th} century. "Scanning electron microscopes (SEM)" were introduced as microscopes that have played an important role in the development of nanoscience and nanotechnology. SEM was described as a microscope that uses a focused beam of electrons to scan a sample and create an image. They also allow objects on the scale of less than 10 nm to be resolved. Similar to SEM, "scanning probe microscopes" as instruments help scientists to characterize nanoscale materials and objects with relative ease and to explore their special properties. Instead of using beams of electrons, they use a metal "probe" to scan the sample surface. Atomic Force Microscope (AFM) is a type of scanning probe microscope, which uses a metal probe that tapers down to a point that has a radius less than 10 nm. AFM scans the surface and detects the interatomic and intermolecular forces between the probe and surface and creates an image. Another probe is Scanning Tunnelling Microscope (STM), which has been mentioned in the first unit of the Nanosense project. The instrument introduced with its probe was described as one atom in size. The tunneling of electrons between the tip and the substance being viewed creates a flow of electrons. The strength of the current and the change in current over time creates an image of the surface of the substance.

Stevens *et al.* (2009) explained how the "Big Idea" of *tools and instrumentation* fit into the curriculum. They stated that beginning at the elementary school, students started to learn about abstract concepts such as "electricity", "atom", "atomic structures", "living organisms", "cells", "cell organelles", "proteins" and "DNA". They believed that introducing tools, instruments and the visuals obtained related to those concepts will facilitate students' conception of such abstract concepts.

In the Turkish high school chemistry curriculum, tools and instruments can also be integrated into the units that relate to the subjects mentioned by Stevens *et al.* (2009). It was also revealed that scanning probe microscopes provide new and more accessible evidence for the existence of atoms and their arrangement in solids.

2.4.5. Nanoscience and Society

The interrelationships between science, technology, and the global economy have an impact on society in many ways. The field of nanotechnology was driven by the aim to advance society (Stevens *et al.,* 2009). The advancement of nanotechnology depends on successful research and development. According to Roco (2003a), there were societal factors, which also have an effect on the advancement of nanotechnology. These factors included education, the training of skilled workers, researchers, policies and economic demands. As Stevens *et al.* (2009) pointed out that nanotechnology has both positive and negative impacts on society. The authors also suggested to direct research toward the potential risks as well as the potential benefits of nanotechnology.

Nanoscience and society is one of the "Big Ideas". The authors suggested that studying the dynamic nature of science and the interplay between scientific discoveries and new technologies motivate students to learn about science since the subject matter is revelant to real life. They suggested to integrate nanotechnology into the curriculum in order to illustrate the dynamic nature of science. This integration also enables students to see how scientists and engineers use their understanding to create new applications that address problems and limitations.

2.5. Students' Awareness of Science and Technology

Scientific literacy was emphasized as one of the key components of science, technology, engineering and mathematics (STEM) education by Laugksch (2000). STEM education aims to improve students' abilities to communicate and discuss science and technology, especially in the issues that are related to everyday situations and social implications. Laugksch (2000) also argued that 'public understanding in science' (PUS) is a suitable terminology to use within the phrase of 'scientific literacy'. On the contrary, Stocklmayer and Gilbert (2002) argued that the phrase of PUS is incompatible with modern theories of learning. A new acceptable model was found by the researcher as 'personal awareness of science and technology' (PAST). They found this model by conducting a study at the Australian National Science and Technology Center where visitors used interactive exhibits. The study showed that an individual's PAST can be used to interpret his/her learning through such exhibits and other ways of science activities. Gilbert (2002) defined public awareness in science and technology as a set of attitudes, a tendency toward science and technology, which are based on beliefs and feelings and which are visible thanks to some skills and behaviors. Gilbert (2002) added that if one person has skills to access scientific and technological knowledge, that person can eventually start to understand the scientific key ideas and the way that they come out. The status of scientific and technological knowledge and its significance relates to personal, social and economic life that can easily be evaluated if a person has a personal awareness of science and technology. According to Stocklmayer and Gilbert (2002), personal meaning making, that is, having ownership via personal experience and exploration, are essential to raise awareness.

The Ministry of EU Affairs reported a document about current situations in Turkey (Ministry for EU Affairs, 2009). In that document, one chapter was called *'Science and Research'*. In that chapter, one agenda item was about 'Science and society'. It was stated that under National Science and Technology Strategy (2005-2010), there were two objectives, which directly related to science and society. One objective was to development human resources for scientists and the other was to raise public awareness of science and society. To raise public awareness, they suggested that faculty members appear on TV channels to give talks on scientific subjects such as natural disasters, economy, energy and traffic. The importance of personal experience and exploration about science and technology applications and the related issues, such as social implementations, were not specifically and clearly emphasized. As for students, the role of open secondary education programs through audiovisual media was emphasized in order to promote scientific awareness towards science. In addition, research project competitions could launch with TUBITAK's support so as to promote scientific research among students.

Within rapid change and development in research and development of science and technology, the goal of development of scientifically literate students becomes more critical. Another point is that, since future scientists and engineers are those students, they also need to understand social implications related to their work. Also, they should feel competent to communicate with scientific and non-scientific community on the issues of research and development.

2.5.1. Students' Awareness and Understanding towards Nanoscience and Nanotechnology

Public awareness and understanding towards nanoscience and nanotechnology was defined as inquiring not only about knowledge of specific terms but also the ability to put those terms in appropriate context (Waldron *et al.,* 2006). The importance of awareness was emphasized by Roco and Bainbridge (2002) as follows:

"Without a wide-spread accurate awareness of the basic facts of nanoscience, public and the policy-makers would not have the knowledge to make informed decisions about nanotechnology and its products".

Waldron *et al.* (2006) also stated that questioning about what public knows about nanotechnology is essential to engage public in the social and political debates about emerging nanotechnology. Batt *et al.* (2008) agreed that although investment in research and development are important, public understanding of nanotechnology can have a positive effect on the implementation of that technology.

In the literature, there were studies that focus on public awareness of nanotechnology (Cobb and Macoubrie, 2004; Scheufele and Lewenstein, 2005; Burri and Bellucci, 2008). According to Waldron *et al.* (2006), the need of raising public awareness of nanotechnology has been well documented in various studies (Weil, 2003; Morrissey, 2004; Schulz, 2002; Service, 2004; Waldron *et al.,* 2005). Public understanding of nanotechnology was determined through various studies (Bainbridge, 2002; Cobb and Macoubrie, 2004; Dowling, 2004).

Despite rapid development in nanotechnology, research literature showed that public has limited awareness in this field (Bainbridge, 2002). In the study of Cobb and Macoubrie (2004), they interviewed with 1536 adults via telephone and found out that public awareness was low, and public understanding was even lower when the participants' technical understanding of nanotechnology was searched. Waldron *et al.* (2006) conducted a study in which they interviewed with 1500 individuals including children of four different age groups: aged younger than 8, aged 8-10, aged 11-13 and aged 14-17 and adults with five different age groups: aged 18-22, aged 23-28, aged 29-39, aged 40-59 and aged 60+. It was found that adults and children had some struggles on the issues of understanding relative scale and sub-visible objects. The study of Batt *et al.* (2008) stated that lack of understanding stemmed from lack of knowledge about science in general but specifically more about difficulty in understanding of size and scale of nanotechnology.

Studies on public awareness of nanotechnology pointed that the role of mass media is currently a key factor influencing how public thinks about nanotechnology (Scheufele and Lewenstein, 2005; Brossard *et al.,* 2009). The study of Waldron *et al.* (2006) showed that most individuals surveyed had heard about nanotechnology from the popular press. The literature also reveals that action of the mass media also differs in terms of placing nanotechnology in their programs. For instance, the U.S media that covers nanotechnology puts more emphasis on positive terms when compared to U.K (Scheufele and Lewenstein, 2005; Nisbet and Scheufele, 2007). In other words, the US citizens' initial attitude toward nanotechnology was positive (Cobb and Macoubrie, 2004). Brossard *et al.* (2009) found that when science newspapers and science programmes on TV mention nanotechnology, public attitude toward nanotechnology were positively affected. The study of Ho *et al.* (2011) examined the media's use of nanoscience and nanotechnology in order to get an idea of how the mass media could be used by experts and public to make judgements about nanoscience and nanotechnology. Their study revealed that science news frames often used by the public as cues to make judgements.

In addition to public awareness of nanotechnology research studies, there were some studies conducted to examine students' awareness and understanding of nanotechnology. For example, in the study of Lu (2009), readiness of freshmen engineering students to study nanotechnology was examined. The results showed that most students learned the term 'nano' from science magazines or as a measurement unit. Only less than 5% of students knew the term 'nano' by attending a nanotechnology education programme. The author emphasized the need of understanding students' personal opinions on many nanotechology issues.

Krajcik *et al.* (2007) suggested that when creating educational programs and materials to develop public understanding of nanotechnology, the focus should be on the basic ideas and principles about nanotechnology.

2.5.2. Students' Risk and Benefit Perceptions of Nanotechnology Applications

Understanding perceptions related to the risk and benefits posed by nanotechnology is an important component of scientific literacy (Garder *et al.,* 2006). To understand perceptions relevant to the risks and benefits of nanotechnology applications, researchers conducted various studies. Most of the studies focused on public perceptions of risks and benefits of nanotechnology (Kahan *et al.,* 2008; Cobb and Macoubrie, 2004; Barnet *et al.,* 2006).

Researchers also pointed out that psychological dynamics associated with cultural cognition shapes public attitudes toward risks and benefits of nanotechnology. Cultural cognition was operationally defined as the tendency of people to base their beliefs about risks and benefits on their cultural judgements (Kahan *et al.,* 2008). In their study, they revealed that people who have predisposition toward technology are more likely to become exposed to information about nanotechnology and they are more likely to react it positively. On the contrary, people lack of predisposition are less likely to become exposed to information about nanotechnology. Moreover, they tend to develop a negative attitude toward nanotechnology. Likewise, the study of Cacciatore *et al*. (2011) examined the mental connections of the US citizens using nanotechnology in the medical field, the military and consumer products and they questioned how these connections moderate the influences of risks and benefits perceptions on attitudes towards nanotechnology. Their results suggested that individuals, who connect nanotechnology with any areas of application such as medical field, take risk perceptions more seriously when forming attitudes towards nanotechnology.

In the study of Cobb and Macoubrie (2004), a national phone survey in the US was carried out and public perceptions about nanotechnology were reported. The results revealed that survey respondents expected the benefits of nanotechnology to be more prevelent than those risks. One significant benefit of nanotechnology was about detecting and treating health diseases, whereas the most stated risk of nanotechnology was about losing personal privacy. According to Gardner *et al.* (2010), perception of risks and benefits of nanotechnology are closely related to specific group of applications, which are common consumer products, health products and advanced technological applications. This research result obtained from a survey of risk perceptions and interviews done with a group of undergraduate engineering students who took material science engineering courses focusing on nanotechnology.

The review of literature showed that most studies in risk and benefit perceptions of nanotechnology deal with either obtaining public perception or undergraduate and graduate university student perception.

3. METHODOLOGY

3.1. Significance of the Study

As nanoscience and nanotechnology have recently been funded areas in research, development of K-12 curriculum and some educational models about nanotechnology are recommended to achieve a modern education system (Roco, 2002). In line with the new emerging nanoscience and nanotechnology developments, the idea of integrating nanoscience into high school curriculum has been supported under funded projects worldwide. *NanoLeap* and *Nanosense Project*, the two large grade 7-12 curriculum development projects funded by NSF in 2004, are given as examples by Greenberg (2009). He also states that nanoscience can either be considered as a new discipline or, based on its interdisciplinary nature, it can be spread throughout the secondary school science curriculum.

As Malsh (2008) argues, the US National Nanotechnology Initiative, German competence networks of nanotechnologies and European Union Framework Programme are key drivers of nanotechnology development on a global scale. The development of such programs and projects could be considered as a turning point in science and technology. As Chank (2006) states nanoscience education can fire young people's imagination and increase their interest in science and technology.

The research area of nanoscience and technology education for secondary school students in Turkey needs a lot of attention (Ak, 2009). With regard to the need of integrating nanoscience and nanotechnology into secondary school classrooms in Turkey, a nanoscience and nanotechnology workshop (NNW) was designed and implemented at Bogazici University in Istanbul. With the nanoscience and nanotechnology workshop (NNW), it was aimed to investigate 11th grade students' awareness and conceptual understanding of nanoscience and nanotechnology while introducing them to such an important emerging area of science education.

This study could be considered as an attempt to introduce nanoscience and nanotechnology education opportunities to students as citizens and future scientists. In addition, this workshop also brought teachers, students, university academics and prospective students together. Also, this study gave high school students an opportunity to spend a whole day at a university's science laboratory. The workshop also enabled teachers to draw their students' attention to one of the emerging science and technology area, which could also be related to many other scientific concepts they cover in their regular curricula.

Similar workshops at universities and institutions about different levels of nanoscience and nanotechnology concepts for different age groups could be developed in the future. Furthermore, the results, which are obtained from this study, can promote development of various other nanoscience and nanotechnology in and out-of-school education resources. Moreover, it can help integrating nanoscience and nanotechnology into secondary school science curriculum.

3.2. Statement of the Problem

As new technologies become available, the need to educate young population about these new technologies is getting more critical. Many worldwide projects are developed and supported to spread nanoscience and nanotechnology education through different grade levels. However, in Turkey, the number of nanoscience and nanotechnology related education programs for young people are limited (Ak, 2009). In fact, there are projects and organizations incorporating nanoscience education at K-12 level. Some of these projects are the European Union funded projects such as *Time for Nano, NanoYou* and *Nanochannels*; *nanotechnology* workshops held in Science Center in Istanbul; "*Understanding Nanotechnology via Virtual Lab" workshop* designed to establish a nanotechnology laboratory at a private high school in Istanbul; university summer school nanotechnology programs in Istanbul, and Sabancı University seminar and workshops organized in collaboration with a university and a private high school. Since nanotechnology has been considered as an emerging science field, new projects and ideas should be developed to inform young people about emerging technologies.

This study has an attempt to reach 11th grade students and increase their awareness and understanding of nanoscience and nanotechnology.

To identify the effects of attending the workshop on 11th grade students' awareness and conceptual understanding of nanoscience and nanotechnology, the following research questions were used as guidelines.

3.2.1. Research Questions and Hypothesis

The research questions of this study were:

i. Will there be any change in 11th grade students' awareness about nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW)?

ii. Will there be any change in 11th grade students' conceptual understanding about nanoscience and nanotechnology after attending NNW?

iii. What outcomes are obtained from the products generated by students who participate in NNW?

In this study, it was hypothesized that;

i. 11th grade students who attend nanoscience and nanotechnology workshop will show an increase in their scores at Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ).

ii. 11th grade students who attend nanoscience and nanotechnology workshop will show an increase in their scores at conceptual understanding test of nanoscience and nanotechnology (NNCUQ).

3.3. Variables & Operational Definitions of Variables

3.3.1. Dependent Variables

Dependent variables of the study were the awareness and conceptual understanding regarding the concepts of nanoscience and nanotechnology. Students' awareness of nanoscience and nanotechnology refers to; having basic knowledge about main nanoscientific and nanotechnological concepts, exposure to nanoscience and nanotechnology in daily life, giving examples to nanotechnology applications, stating benefits and risks of nanotechnology. Conceptual understanding covers the basic concepts of nanoscience and nanotechnology such as size and scale, hydrophobic and hydrophilic surfaces and also scientific concepts from high school chemistry curriculum such as intermolecular forces and surface tension.

To measure students' awareness of nanoscience and nanotechnology, 5-degree likert-type questionnaire called "Nanoscience and Nanotechnology Awareness Questionnaire" (NNAQ) (See Appendix A) and semi-structured interviews (See Appendix J) were used. Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ) were developed by the researcher based on the questionnaire developed by Dyehouse *et al.* (2008) and it was pilot tested for its validity and reliability.

Students' conceptual understanding regarding the concepts in nanoscience and nanotechnology was measured with "Nanoscience and Nanotechnology Conceptual Understanding Questionnaire" (NNCUQ) (See Appendix B), which contained an open-ended question, also semi-structured interviews including some questions about basic concepts of nanoscience and nanotechnology (See Appendix J).

Students' interest to workshop is measured by open-ended questions of "Nanoscience and Nanotechnology Workshop Evaluation Questionnaire" (NNWEQ) (See Appendix C), which was given at the end of the workshop.

3.3.2. Independent Variable

The independent variable of this study is the workshop (NNW), which was designed as an introduction to nanoscience and nanotechnology for high school 11th grade science students. The high school students' prior science knowledge that forms the basis of understanding nanoscience and nanotechnology was considered while designing the NNW. Schank *et al.,* (2010) stated that student's prior knowledge shall be considered as an important strategy for success in learning nanoscience related topics.

3.4. Nanoscience and Nanotechnology Workshop (NNW)

The basis of design and implemention of the NNW was based on various nanoscience and nanotechnology education projects from the United States and Germany. *NanoLeap* and *NanoSense Project's,* two significant 7th-12th grade curriculum development projects, which were funded by NSF in 2004 (Greenberg, 2009), general ideas and goals were used as the starting point of the design of the workshop. NanoLeap project's goals were exploring nanoscale science, technology, engineering, and mathematics concepts fitting into high school physical science, and chemistry classes supporting students in learning core science concepts. Moreover, there was one more goal, finding out better approaches to develop instructional materials in the area of nanoscale science, technology, engineering, and mathematics. For NanoSense Project, the main goal was helping high school students to understand science concepts about nanoscale science and technology. This project aimed to create instructional units to help students understanding underlying principles, applications, and implications of nanoscale science. The ideas that form the basis of the workshop were adapted by the researcher based on the desired outcomes identified by NSF funded NanoLeap Project team.

i. The common concepts of nanoscience and nanotechnology with high school physics, chemistry and biology should be explored.

ii. Interdisciplinary nature of nanoscience and nanotechnology should be emphasized in the content of the workshop.

iii. Instructional materials of the workshop should support inquiry based teaching and learning.

iv. Activities in the workshop should increase the levels of interest and engagement in learning science.

v. The workshop should increase the understanding of core science concepts.

vi. The workshop should increase the understanding of core nanoscience and nanotechnology concepts, their applications, and social implementations refer to benefits and risks.

The initial idea for this study originated from the study conducted by Akaygün (2010a,b). In the studies, the researcher aimed to investigate pre-service science and mathematics teachers' initial knowledge and the attitudes towards nanoscience and nanotechnology. Moreover, during the research study, a "Nanoscience Workshop" was created by preservice teachers to implement the workshop to another group of preservice teachers. With respect to the study results, a similar introductory nanoscience and nanotechnology workshop was planned to be developed and implemented with secondary school students.

This workshop was composed of presentations, demonstrations and selected activities considering suggestions made in the literature about designing nanoscience and nanotechnology education materials and programs for secondary school level. Considering the main scientific concepts needed for an introductory level nanoscience and nanotechnology related workshop, based on the prerequisite knowledge of students, 11th grade level students were chosen as participants of the workshop.

3.4.1. Design of Nanoscience and Nanotechnology Workshop (NNW)

The development and implementation process of the study consists of different parts:

3.4.1.1. Part 1: Identification of main concepts needed for an introduction to nanoscience and nanotechnology for high school level. At the beginning of the study, the literature was reviewed for the most commonly emphasized nanoscience and nanotechnology concepts that were needed to understand the basis of nanoscience and nanotechnology. The main concepts were identified then; these suggested concepts were checked if they were consistent with revised high school chemistry, physics and biology curriculum. Also suggestions from the study of Hutchinson (2007) were taken into consideration. It is suggested to consider some of characteristics of nanoscience concepts to increase the interest of students' which is a key factor for learning. The suggested characteristics of nanoscience concepts were related to "general curiosity", "personal interests", and relation to everyday life, "hands-on/experimentation". The concepts were checked if they have these four characteristics. Since this workshop was planned to be an introductory workshop for high school students, main concepts were specified as:

i. Size and scale

ii. Properties of matter

iii. Ferro fluids

iv. Instruments: STM&AFM

v. Dominant Forces

vi. Surface Tension

vii. Hydrophilic and hydrophobic surfaces

viii. Lotus Effect

ix. Ethical issues, risks and benefits for the future

x. Product Design: What is learnt so far?

Except the knowledge of "size and scale", "properties of matter", "dominant forces", "surface tension", "terms of hydrophilic and hydrophobic", the rest of the concepts are new to high school students according to available chemistry, physics and biology curriculum. For instance, the terms of "hydrophobic and hydrophilic" were introduced in 9^{th} grade chemistry curriculum in the second chapter, which was about "Compounds". The related objective to this subject was stated as *"Students will show hydrophilic and hydrophobic parts of an organic compound"* (Talim Terbiye Kurulu Başkanlığı, 2007). Because of this, the grade level, which the curriculum related concepts could be best understood, was considered to be 11^{th} grade. Students got familiar with size and scale, properties of matter, terms of hydrophilic and hydrophobic at 9^{th} grade; with intermolecular forces, surface tension in second semester of 10^{th} grade. Since the workshop was planned to conduct in the first semester, 11^{th} grade students were preferred. 11^{th} grade students were preferred considering their prior science knowledge on these subjects.

3.4.1.2. Part 2: Identification of nanoscience and nanotechnology education materials suitable for high school level. After the concepts were specified, the literature was reviewed for designating worldwide projects, which were about nanoscience and nanotechnology education for secondary school level. The sources of the projects were National Center for Learning and Teaching in Nanoscale Science and Engineering; the NanoSense project; the NanoLeap project; Nanoscale Informal Science Education and NanoSchoolBox. The activities, which were needed for basic understanding of nanoscience and nanotechnology, were selected according to the following principles which were identified by the researcher.

i. The activities should be safe in order to apply them in a laboratory.

ii. The activities should be consistent with the concepts.

iii. Each activity should address a different concept.

iv. The materials of the activities shouldn't be complicated so that they can be applied at different places after this workshop.

After selecting the activities, they were revised and adapted for the workshop. Since the projects and the materials were reachable from Internet for the public use, taking permission for using them was not required. The selected activities were: “Cutting it Down” which was created by Nanoscale Informal Science Education (NISE), “Black Box” activity which was one of the laboratory activities included in “Tools of the Nanosciences” chapter of NanoSense Project, “Lotus Leaf Effect” activity was created by University of Wisconsin-Madison Materials Research, Science and Engineering Center (MRSEC). The activity of “Discussion about “Risks and Benefits of Nanotechnology” and the activity of “Create Your Own Nano Product” were designed by the researcher.

3.4.1.3. Part 3: Specification of goals for the workshop. The aim for such a workshop was to introduce and take attention of students’ to such an important emerging area of science and technology, and help them relate many scientific concepts they cover in their regular curricula and see how nanoscience and nanotechnology is an interdisciplinary subject. In respect to create learning experiences of students in the workshop, the following goals were identified by the researcher:

i. Introduce the nanoscience and technology as an interdisciplinary element

ii. Increase the scientific literacy in nanoscience and nanotechnology

iii. Increase understanding of nanoscale science, technology and core science concepts

iv. Get familiar to recent applications, and future careers

v. Relate chemistry concepts from the curriculum to nanoscience concepts

vi. Awareness of risks and benefits of nanotechnology

3.4.1.4. Part 4: Design of the content of the Workshop. This workshop was designed to provide a one-day introduction to nanoscience and nanotechnology for high school students with very limited time. It included a presentation, visual demonstrations, hands-on activities accompanied with their worksheets, group discussions, poster design and follow up. The researcher has a role of implementing the study, making presentations before, during and after the activities. During the activities, researcher observed the groups. Design of the content part also included subsections in it. Each subsection had its own design and development process that came with production of its own materials. The subsections are shown in Table 3.1 and are explained in details.

Table 3.1. The subsections of nanoscience and nanotechnology workshop (NNW).

Time	The Subsections of NNW
9.00-9.30	Welcome
9.30-10.15	Presentation: Introduction to Nanoscience and Nanotechnology
10.15-10.45	Activity 1: Can we cut down into nanoscale?
10.45-11.45	Activity 2: How can we see in nanoscale?
11.45-13.15	Lunch Break
13.20-14.20	Activity 3: Solving the Mystery of Lotus Effect
14.20-14.50	Activity 4: Discussion about "Risks and Benefits of Nanotechnology"
15.10-15.40	Activity 5: Create Your Own Nano Product
15.40-16.00	Post tests, Workshop Evaluation Form

The introductory PowerPoint presentation (See Appendix D) was prepared to use at the beginning of the workshop. Time required for the presentation was 40 minutes. The researcher who is also called project leader of the workshop presented this part. The slides of the presentation generally introduced what nanoscience and nanotechnology were brief overviews of the history, what was interesting about science at nanoscale, what kind of technological developments occurred and how they impacted our lives.

The presentation started with a short part from an old movie called "The man in the white suit". It was about a chemist who invents a fiber that repels dirt, everlastingly strong and luminous in a fabric factory. This movie part included in the presentation for taking students' attention and makes them think about the possible relation between the movie and the nanoscience and nanotechnology. Also the movie provided following questions to make students to think one step further. "Do you think that movies become real?", "What has changed in movies since 1950's?" With an example of a liquid metal robot from a movie called "Terminator 2", students were made to think further with a question of "Is this soon to be real?" Then it was emphasized how fast technological developments occurred and it was asked students that "Why do technological developments occur?" Other suggestions of students were added to answer of curiosity, need, money and power. The students' attention was taken to the estimation which states the effect of nanotechnology to a world market volume of up to US$3 trillion by 2015. This information was followed by the question of "Does World ready for this growth?" "Are there enough number of scientist?" The estimated number of nanotechnology workforce needed by 2015, which is 2 million people (Roco and Bainbridge, 2001), also shared with students. Then, nanotechnology was defined as "understanding and control of matter at the dimensions of 1 to 100 nanometers enable novel applications" (National Nanotechnology Initiative, 2006). After sharing this definition, need for a more detailed explanation for nanoscience and nanotechnology was added. The presentation continued with brief history of nanotechnology based on information given in Nanotechnology Research Foundation. It started from 18th century two colored ancient Roman vases, window glass paintings. Photography was given as an example from 19th century. Richard Feynman was introduced with his famous quota "There is plenty of room at the bottom" as the person who first introduced the nanotechnology idea. Then Nario Taniguchi from Tokyo Science University is introduced as the first person, who defined the term "Nanotechnology" in 1974. Then Dr. K. Eric Drexler, who developed nanoscale devices such as molecular machinery in 1977, was introduced. The invention of Scanning Tunneling Microscope (STM) by Heinrich Rohrer and his colleagues, discovery of buckyball, and carbon nanotubes were mentioned. In 1990's, laser manipulation of individual atoms, in 2000's new techniques such as nano lithography was introduced.

After the history part, the meaning of the term “nano” and “nanometer” were introduced. To enable a better understanding of nanoscale, PowerofTen java tutorial was shown. Then Scale Activity (See Appendix E) was introduced. Each group was given pictures of a box, baseball, marble, salt grain, hair, red blood cells, bacteria, virus, proteins, big molecules, and atoms and molecules. These pictures were taken from NanoSense project, “Size Matters” module. Groups were also given an empty scale to match the pictures with right scales. The activity required 10 minutes; groups checked their results afterwards.

This scale activity was followed with a demonstration of “ferrofluid” where it was originated from NanoSense Project. The aim of this demonstration was to emphasize the nano-sized particle of a given substance exhibiting different properties than larger sized particles of the same substance. Japanese artist’s, Sachiko Kodama’s, ferrofluid sculptures were also shown. One more example was given about nano gold particles which were used in window stains and different colors reflected according to different nano sizes. Other important principle, surface to volume ratio was introduced.

The interdisciplinary nature of nanoscience and nanotechnology was mentioned with a chart that showed physics, material science, information technology, microelectronics, biology, biotechnology, biochemistry and chemistry as example of fields that interrelates with new technology.

Bottom-up and top-down approaches were explained as manufacturing processes with two simulations taken from *NanoHUB project*, then some important nanotechnological applications were introduced starting from use of carbon nano films in many areas; solar cells, touch screen, electro active devices, sport materials, OLED’s, paints, and so on. Use of buckyballs in cosmetics was emphasized. Nanotechnological applications about health were introduced with examples of anti cancer gold nano particles, nano robots, and early diagnosis with quantum dots. Other applications about data storage and nano chips were mentioned. Various applications of nanolithography technique were shown. Then, nanotechnology in food sector, cosmetics, textiles, and automotives were introduced with real life applications. Air and water filter applications, anti fog and self-cleaning properties of nano paints were also given as examples.

Nanotechnology in Turkey was mentioned with introducing National Nanotechnology Research Center (UNAM) in Ankara. Nanotechnology education opportunities at some universities and institutes in graduate levels were also mentioned. Some of the applications such as converting TNT dynamites to fertilizers, finger sign detectors with nano particles, protection of historical places with nano particles were shared. The risks of nanotechnology were emphasized. The future of nanotechnology was introduced with some future projects that have already been planned.

Beside the introduction presentation that was explained above, the main body of the workshop consisted of four different activities. Each activity related to one or more nanoscience and nanotechnology concepts specified at the beginning of the design process of the workshop. The activities had some important elements to be discussed in details. These elements were group work, worksheets, materials, and explanations.

The activities were designed for group work that is favored by constructivism, which enables learning with creating meaning from experience (Bednar *et al.,* 1995). The size of the groups was 4-5. In each group, one prospective teacher called "mentor" facilitated the activities. They facilitate learning by encouraging for inquiry, exploration and give guiding to groups at the beginning and during the activities. Meanwhile, students were actively participated to the learning process by doing hands-on activities, taking responsibility in group work, filling out given activity sheets, and sharing and discussing activity results. The researcher assigned groups randomly. Then researcher sent the arranged group list to the teacher to check the group dynamics in order to lessen misbehaviors during the workshop.

The activities included one individual worksheet and a group worksheet. Individual worksheet questions had two parts. First part had to be answered before the activity. It provided answers for the question of *"what students have already known?"* Second part had to be answered after the activity. It provided answers for the question of *"what sort of knowledge students have gained?"* At the beginning of the activity, mentor gave one individual worksheet to members of the group. After they fill out the first part of the individual worksheet, mentor selected one student and gave him/her the responsibility to fill in the group worksheet according to common group answers. Group worksheets had three main parts. First part had to be answered before the activity. It provided answers for the question of *"what students have already known?"* It was similar to individual worksheet, but main difference was that it was expected to get group answers after a group discussion. Second part consisted of questions that helped students to follow hands-on activities and to help them to make observations in details. In each question, groups were asked to give an answer to questions and to write their answers to group worksheet.

The role of the mentors here was encouraging students for inquiry and exploration with the open-ended questions covered in the worksheet. Third part of the group worksheet was similar to the second part of the individual worksheet. This part had to be answered after the activity. It provided answers for the question of *"what sort of knowledge students have gained?"* Students filled in the second part of the individual worksheet before filling in the last part of the group worksheet. After each activity, mentors collected both individual and group worksheets to be evaluated.

As it was mentioned before, activities form the main structure of the workshop. This workshop, which was designed as an introduction to nanoscience and nanotechnology workshop, had an important aspect that it introduces the main concepts of nanoscience and nanotechnology with five different hands-on group activities. As it was explained, two different kinds of worksheets were provided for each activity separately. Other element that activities had common was an explanation part involves at the beginning or in the middle of the activities. Each activity sheet consisted of one or two activities in it. These activities were also called "missions" in the activities.

In the following sections, each of the five activities was summarized with their purposes. Individual and group activity sheets for each activity can be found in Appendix F in details:

Activity 1, "Makasla keserek nano boyuta küçültebilir miyiz?-Can we cut down into nanoscale?" was adapted from the activity "Cutting it Down" which was created by Nanoscale Informal Science Education (NISE). The purpose of this activity was making students understand that nanoscale is very small and that scientists working at nanoscale require special tools. This activity required fifteen to twenty minutes. As similar to other activities, first students filled out the individual worksheets then they started to work on group activity sheet.

At the beginning of the activity, each student was given 150 mm x 5 mm piece of paper and a pair of scissors. Mentor of the group told the group what the paper's dimensions were. It was also mentioned that they were also given a calculator, a ruler, and a data worksheet that they could record the times of cut and size of the cut paper. Mentor told the group to begin cutting the strip of paper crosswise and to continue cutting it in half as many times as they can. Students were reminded to keep track of the number of cuts they made and to record them to their data worksheet.

After groups were done with cutting till the paper became impossible to cut with scissors, the mentors asked students to fill in the questions on their activity sheet. Questions asked students to guess how many times they could think of cutting the paper before it became impossible to cut with the scissors; the size of the smallest paper that they could have, if macro scale objects, like scissors could be used on the nanoscale or not, whether they thought of any way to cut the paper any smaller, number of times they would have to cut the paper to reach a 1 nanometer long piece. After they answered these questions as a group, each student filled in the individual activity sheet and wrote their conclusion about the activity, and then they filled in the group activity sheet for the same purpose.

As a closing process, the project leader showed few slides (See Appendix G) that summarized the answer of the questions and purpose of the activity. The rationale of this activity was to draw attention to how small nanoscale is and that scientists working at nanoscale require special tools rather than using macroscopic devices.

Activity 2, "Nano boyutta nasıl görüyoruz?-How can we see in nanoscale?" involved two different missions. One was Black Box activity; the second one was finding an unknown object's size in a closed box. The first activity was adapted from the activity "Black Box" which was one of the laboratory activities included in "Tools of the Nanosciences" chapter of NanoSense Project. In this activity, students aimed to understand how scanning probe microscopes for seeing and manipulating increase our ability to investigate and innovate. The other point was to get students thinking about how the scanning tunneling microscopes (STM) which is a type of scanning probe microscope give us a picture of the surface of the atoms and how challenging is to use nano metric size probes in these microscopes.

As similar to other activities, first students filled in the individual worksheets then they started to work on group activity sheet. This activity gave students to use different probes to "see" the surface of a closed box in which the bottom of the box was covered with unknown materials. As the equipments of the activity; one shoebox, three different probes: cotton swab probe, a very thin wooden stick and a thick wooden stick, was given to each group. For the preparation of the box, variety of objects of different compositions and shapes such as beads, Lego, metal needles in various arrangements and patterns were glued to the bottom of each box. Each group received their own unique surface in box and work with their own set. Then, a small hole was cut close to top of the box, so that students could reach all the parts of the bottom surface. At the beginning of the activity students were asked to place three of the probes one by one to the center of the hole and guess what the bottom of the surface looks like. And they were also asked to draw a rough sketch of the surface on the chart in their group activity sheet. After completing this chart, three questions were asked to students. *"What kinds of information about the bottom surface were you able to deduce?", "Which probe helps you to get a better idea of what the bottom surface looks like?", and "What happens if you press too hard on the surface or the pattern?"* This first part of the activity required 15 minutes, after completing this part, mentors introduced the second part of the mission. The purpose of the activity was to find out shape and size of an object, which was placed in a closed box. By doing this activity, students might understand the working mechanism and the principles of Scanning Probe Microscopes. The materials used in this activity were, one rectangular shape plastic object glued in an empty box, a sewing awl and a calculator. Mentors explained students that by using a sewing awl and moving it up and down on the box, they would designate the place of the object and calculate its size and tell the shape of it. The guiding questions were *"What is the shape of the object in the box?" "What is the size of the object?"* After all groups could answer the questions, the project leader gives a presentation that was about 15 minutes. This presentation included basic information on the principles of two types of scanning probe microscopes, which were scanning tunneling microscope and atomic force microscope. The usage areas of these types of microscopes, which were STM and AFM with respect to nanotechnology, were also emphasized. Short videos and animations of STM and AFM were shown. In the last two workshop implementations, new slides about a visit to Bogazici University Research and Development Center had been included to the presentation. The content was about two short interview videos. The first interview was conducted with a researcher who is responsible from Electron Microscopy; the other interview was conducted with a research assistant who is responsible from AFM. Since most of the students at least heard the term of electron microscope had an opportunity to hear basic principles and saw how an electron microscope works from a real researcher. AFM was a brand new microscope for many students. It was also an opportunity for them see a real AFM microscope that is commonly used in various research and developments in Bogazici University.

After introducing the microscopes, groups were asked to respond two questions "What do you think that box and stick represents in the first activity *"What do you think that box and sewing awl represents in the first activity?"* Then, project took each group's response and let them to compare their answers with the answers on the in the presentation. The activity concluded with filling in individual and group conclusions.

Activity 3, "Lotus yaprağının sırrını çözelim.-Solving the mystery of lotus effect" was adapted from "Lotus Leaf Effect" activity that was created by University of Wisconsin-Madison Materials Research, Science and Engineering Center (MRSEC). This activity had also consisted of two missions (See Appendix H). The first activity was called "Water Repellent Test". Before the test, mentors gave two different leaves to each group. All needed to do was dropping one drop of water on each of leaves from a pipette. Students were asked to describe the shape of the water droplet on leaves and to compare these two leaves according to the shapes of water droplets on them. This observation proceeded with two *questions "Why do you think that water droplets take such shapes?" "Observe what happens if you apply force on water droplet. Does its shape change? If yes, explain why"*. Students discussed the answers and wrote a group decision. The next step was testing water repellent on four different fabrics. Fabrics were cotton fabric, synthetic fabric, nano fabric and nano-coated fabric. Students were asked to observe if the fabrics were water repellent or not and to describe the shape of the water droplet on fabrics. Then, two questions were asked, as *"Are there any similarities between your observations of water droplets on leaves and fabrics "Do you think every water resistant fabric is water repellent?"* The group answers were followed by the presentation, which was to explain the reasons behind observing water repellent surfaces. It started with discussion of group answers to water repellency test. Then, the project leader asked students if they heard about the terms of "hydrophilic" and "hydrophobic". After responses of students were taken, "hydrophilic and hydrophobic surfaces" were introduced. At this point, a lotus plant was shown to students and was asked if they had recognized this plant or not. Since lotus plant was an example to hydrophobic surfaces, a short video was introduced to show how a water drop stays and takes a perfect spherical shape on a lotus plant. Then some pictures of lotus plant's scanning electron microscope (SEM) analysis were shown to students to emphasize the properties of its unique structure. Lotus plant has wax crystals, which actually make the surface of the leaf rough. This nano and micro sized wax crystals make lotus plants "super hydrophobic". At this point, the concept of "contact angle" was introduced to students by emphasizing that measurement of contact angle is necessary to decide if a surface is hydrophilic or hydrophobic. Moreover, the scientific principles of "Lotus Effect" discussed with students. The project leader emphasized the concepts of "Surface Tension" and "Intermolecular Forces". The meanings of these two concepts were asked to students. The chart that showed the classification of surfaces as super hydrophobic, hydrophobic, and hydrophilic and super hydrophilic according to surface angles had shown to students. In order to relate the water repellent test activity of leaves and fabrics with these new concepts of contact angle, hydrophobic and hydrophilic surfaces, groups were asked to specify each leaf and the fabric as super hydrophobic, hydrophobic, hydrophilic and super hydrophilic according to estimated contact angles.

After this discussion, "contact angle instrument" which belonged to chemistry department in Bogazici University was introduced to workshop participants. The research assistant from chemistry department did this demonstration. During the contact angle measurement demonstration, one piece of nano-coated tissue paper, one piece of normal tissue paper, nano fabric and a normal cotton fabric were used as samples. This gave students a chance to learn how contact angle is measured and to see the difference between super hydrophobic, hydrophobic, hydrophilic and super hydrophilic surfaces.

Contact angle measurement, was followed by the second mission, which was about “self-cleaning” property. The idea of this activity was to understand the self-cleaning concepts that were related to Lotus effect, which is an important principle in nanoscience and nanotechnology. Before starting the activity, students were given one hydrophobic leaf and a nano fabric. They were asked to put some black pepper that represents dust on the leaves and to add some drops of water with a pipette to the contaminated surface and to tilt the leaf so that the drops can roll away. The mentors guided the students to fill in the observation chart. Afterwards, the principle of self-cleaning effect was explained and some SEM analysis of lotus leaf while dust was rolling away with the water droplet.

To help students understanding and making this new knowledge meaningful, these Lotus effect and self-cleaning principles and nanotechnology applications that were based on these principles were introduced. The subjects emphasized were briefly given as “Lotus effect on nano-coated surfaces”, “Lotus effect in textile applications”, “Biomimetics: gecko and jumping spider”, “nano-coatings for self cleaning”. This presentation was given in Appendix H.

Activity 4, “Nanoteknolojinin getirdiği riskler ve faydalar.-Discussion about risks and benefits of nanotechnology” conducted in two different ways. Two of the schools conducted the activity by separation of the whole group into two big groups. In other words, three groups out of six combined and formed one group; the rest three groups combined and formed another group. One group was asked to list risks of nanotechnology; the other group was asked to list benefits of nanotechnology. When the group works were completed, groups shared their opinions and reached to a consensus. This discussion part was followed by a short presentation (Appendix I) that summarized some of risks and benefits of nanotechnology. Second way of conducting this activity was that each group, work in their small groups to discuss and list both risks and benefits of nanotechnology. When the group works were completed, groups shared their opinions with other groups. This discussion part was followed by a short presentation that summarizes some of risks and benefits of nanotechnology. The different ways were followed since researcher would compare and would decide which way of application was effective.

The last activity, Activity 5, “Kendi nano ürününü yarat.-Create your own nano product” asked each group to design a nano product. There was no revision on this activity, so it was similar to the one in first implementation. Nano related product design followed by group presentations. It was the end of the activities. Students introduced BU NANO facebook group, their emails were collected to add them in-group by the researcher. Post-NNAQ and post-NNCUQ were distributed.

3.5. Sample

This study was implemented in the physics education laboratory of Secondary School Science and Mathematics Education Department in Bogazici University, in Istanbul. Three different high schools from Istanbul attended to the workshops. Two of the schools were private schools and the other was a public school. In this study, schools were named as Pr1, Pr2 and Pu. Since two different classrooms of the same public school attended in two different times; first attended classroom named as Pu1 and the second attended classroom named as Pu2. Pr1 was the first private school that attended the workshop; Pr2 was the second private school that attended the workshop. All schools were selected due to their convenience for the researcher. Since the workshops took place during a whole weekday, first the researcher contacted with several schools and announced the workshop and the days that workshops were planned. Three schools accepted to participate in the workshop and bring their students to Bogazici University. It was planned to specify two private schools and two public schools. This also meant that the workshop planned to be conducted four different days.

The sample of the study planned to be consisted of 102 students in total. Only 6 of them were 12^{th} graders, the rest were 11^{th} graders. Fifty-two students were from private schools. Only 6 of them were 12^{th} graders from Pr2. Moreover, 50 students from public school consist of two different classrooms; Pu1 and Pu2. However, on the workshop day, some of the students did not show up. Then, sample size reduced to number of 79 students in total. The number of students attended to workshop from Pr1 was 18; from Pr2, 19 (6 of them were 12^{th} graders); from Pu1, 17 and from Pu2, 25 with full attendance.

The researcher planned to include only 11th grade science students to this workshop series. On the other hand, the reason of having six of 12th graders in the workshop was, the chemistry teacher of Pr2 wanted these students to attend this workshop, since they would graduated at the end of the year and it would be good to inform them about emerging nanotechnology. For the rest of the students, there was no special selection process. The chemistry teachers took their whole class to this workshop as if they were attending a scientific field trip, which took place at a university. As a result, there was also no control group in this study. The researcher who was also called project leader led the workshops.

Table 3.2. Sample of the study.

	Private or Public	Grade Level	Teacher	Number of Students
Pr1	Private	11th	Teacher Pr1	18
Pr2	Private	11th,12th	Teacher Pr2	19
Pu1	Public	11th	Teacher Pu1	17
Pu2	Public	11th	Teacher Pu2	25

Table 3.3. Frequency table for the sample.

<table>
<tr><td></td><td></td><td colspan="2">Gender</td><td></td></tr>
<tr><td></td><td>Grade</td><td>Female</td><td>Male</td><td>Total</td></tr>
<tr><td>Pr1</td><td>11th</td><td>6</td><td>12</td><td>18</td></tr>
<tr><td rowspan="2">Pr2</td><td>11th</td><td>5</td><td>9</td><td rowspan="2">19</td></tr>
<tr><td>12th</td><td>1</td><td>5</td></tr>
<tr><td>Pu1</td><td>11th</td><td>10</td><td>7</td><td>17</td></tr>
<tr><td>Pu2</td><td>11th</td><td>10</td><td>15</td><td>25</td></tr>
<tr><td>Total</td><td></td><td>32</td><td>49</td><td>79</td></tr>
</table>

3.6. Design

The aim of the study was to develop a nanoscience and nanotechnology workshop (NNW) and determine the effectiveness of it by examining the change in the nanoscience and nanotechnology awareness of 11^{th} grade high school students and also examining their conceptual changes on nanoscience and nanotechnology related concepts. And also the video recordings, artifacts and notes taken by the researcher were analyzed to determine the effectiveness of the workshop.

As a conclusion, obviously, this study was designed as a mixed method research. It consisted of both quantitative and qualitative parts.

As quantitative parts; examining the awareness and the conceptual change of students with developed instruments for both private and public school students could be considered. The data obtained from private schools and the data obtained from public schools were compared. Also comparison between two private schools and comparison between two classes of the same public school were done. As a result, first way to analyze the effectiveness of the workshop was using by pre-test-post-test design (pre-experimental design).

Also in the qualitative part, examination of the awareness and the conceptual change of students were done by conducting pre and post interviews. Additionally, each group work was video recorded separately and every artifact from workshop was collected by the researcher during the workshop. But these video recordings were not analyzed for this thesis.

Therefore, the effectiveness of NNW was analyzed under mixed type of research that quantitative part was planned as pre-experimental design (pre-test-post-test design) and in the qualitative part, the interviews were conducted before and after the workshop. Add to this, video recordings, observation notes and artifacts were other main source for qualitative analysis.

3.7. Instruments

In this study, five different instruments were used. They were "Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ)" (See Appendix A), "Conceptual Understanding of Nanoscience and Nanotechnology Questionnaire (NNCUQ)" (See Appendix B), "Workshop Evaluation Questionnaire (NNWEQ)" (See Appendix C) and pre and post-interview questions. The first two instruments were developed to determine students' awareness and conceptual understanding in nanoscience and nanotechnology. The third one was developed to learn students' feedbacks and recommendations about the workshop. The interview questions were developed to get more detailed information about students' views and knowledge about nanoscience and nanotechnology.

3.7.1. Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ)

Taking the items of "Nanotechnology Awareness Instrument", which was developed by Dyehouse *et al.* (2008) as reference, developed the Nanoscience & Nanotechnology Awareness Questionnaire (NNAQ) (See Appendix A). In their article, the authors stated that this instrument might be useful for K-12 teachers who want to determine pre-post awareness and exposure to nanotechnology and how to affect students' motivation and factual knowledge to further studies in nanotechnology. Add to this, the instrument was designed for use before and after an intervention or program so that pre and post differences could be obtained.

However, the nanoscience and nanotechnology awareness instrument of this study did not completely adapted from Nanotechnology Awareness Instrument, which was developed by Dyehouse *et al.* (2008). The items of nano-awareness and nano-exposure, nano-motivation subscales were taken as examples, since the three subscales appeared to be reliable measures of awareness, exposure and motivation. Internal consistency reliability was stated as high for the subscales by the authors of the study. Cronbach's alpha for the nano-awareness was α= 0.91, nano-exposure was α=0.82 and nano-motivation has was α=0.94. These coefficients indicated a satisfactory level of internal consistency reliability. The construct validity of the instrument was analyzed by exploratory factor analysis. As it is recommended to use the "Nanotechnology Awareness

Instrument", which was developed by Dyehouse *et al.* (2008) with variety of students and interventions designed to encourage interest in nanotechnology, the items of the original instrument revised by the researcher and some items were changed with new items. Before implementing this instrument (NNAQ) in workshops, for the reliability of the instrument, a pilot-test was conducted before the workshop with the students who had no experience or any knowledge about the nanotechnology workshop. The Cronbach's alpha for the entire scale was calculated as α=0.89.

The Nanoscience & Nanotechnology Awareness Questionnaire (NNAQ) was composed of one part that has 20 items. Colleagues and experts in educational research and scale construction reviewed the items. Such review of the items and their face validity led to the deletion, modification and inclusion of new items prior to field-testing. Three items were extracted from an initial 23-item first version of scale administered one time to 10 preservice teachers who were attending science, technology and society course.

In completing NNAQ, respondent students were asked to report their awareness of nanoscience and nanotechnology as high school students by using a 5-point Likert-type scale with 1 (strongly disagree), 2 (disagree), 3 (undecided), 4 (agree), 5 (strongly agree).

The 23 items of initial version of instrument was reflecting a prior understanding of the literature. The content validity of the instrument was established by factorial analysis of variances and items, which were categorized in subscales. The reliability analysis of the instrument was conducted with the data obtained from each workshop. Cronbach's alpha and item- total correlation coefficients were computed to find the internal consistency of the instrument. Reliability analysis was conducted with both the pre and posttest scores of the students participating to the study from the public and private school.

The instrument was administered to 79 high school students from three different schools. In each workshop, the instrument was given to students as a pre-test before the study when students had no experience related to the science center visit. The instrument was also given to the students at the end of the workshop.

3.7.2. Nanoscience & Nanotechnology Conceptual Understanding Questionnaire (NNCUQ)

Nanoscience and Nanotechnology Conceptual Understanding Questionnaire (NNCUQ) (See Appendix B) was designed, based on the conceptual understanding of nanoscience and nanotechnology instruments found in literature. The instrument was from a research study of Akaygün (2010a, b) which was presented as a poster in 10th European Conference on Research in Chemistry Education (ECRICE) and presented as a paper in 9th National Science and Mathematics Education Congress. The common points in suggested instruments were taken into consideration, revised and added to NNCUQ as items. Tertiary Students Nanoscience/Nanotechnology Survey (Akaygün, 2010a, b) consists of two parts. One part measures "understanding of scale" and the second part measures "awareness of nanoscience and nanotechnology". "The Understanding of Scale" includes questions about putting the given twelve species such as water molecule, virus, red blood cells in size order, writing the approximate size of them by using the same unit (meters or nanometers), grouping them according to their relative sizes and writing down the equivalents of given scales in meters. The subsections of this study also suggested in the measurement of size and scale understanding literature. One research study of Delgado (2009) emphasized the importance of understanding size and scale in science education. In the study of Delgado (2009), a size and scale interview conducted. This interview also asked questions related to ordering by size of the objects such as diameter of an atom, diameter of a virus and diameter of a cell from largest to smallest, making groups of objects with similar size, estimating approximate size of the objects in terms of a familiar object and also estimating absolute size. These selected objects were specified as scientifically important objects that are potential landmark objects (as cited in Delgado, 2009). It was also important to include submicroscopic objects, since students' accuracy for submicroscopic objects is lower (Tretty *et al.,* 2006).

According to these common subsections, this instrument (NNCUQ) had an "Understanding of Scale" part that consisted of questions about putting given ten species. These are; water molecule, virus, red blood cells, width of a human hair, head of a pin, width of DNA, bacillus bacteria, electron, size of oxygen atom in size order, writing the approximate size of them in terms of a familiar object which is a pin head with 1 mm, grouping them according to their relative sizes. Writing down the equivalents of given scales in meters part were not included in questionnaire since it is assumed that students know how to convert one scale to another.

Other than the "Understanding of Scale" part, the instrument (NNCUQ) had two more parts. First part was about "Understanding of Nanoscience and Nanotechnology"; this part included questions like *"have you heard about the given terms?"* (The terms mentioned here were nanoscience, nanotechnology, nano particles, and carbon nanotube, scanning tunneling microscope (STM) and/or atomic force microscopy (AFM)). The items were in multiple-choice format. Choices are *"a) I haven't heard this term, can't explain; b) I have heard about it but I can't explain what it means: c) I have heard. I think…"*. If the third choice had selected, it would require an explanation. Apart from this, there was also a second question in open-ended format. This question looked for the information about students' knowledge of any applications of nanotechnology. The question was *"Do you know any applications of nanotechnology If yes, in which fields? Give examples. Where did you hear about them?"*

The last part of the Instrument (NNCUQ) was "Forces and Interactions". This part with three open-ended questions was added since the concepts of intermolecular forces, hydrophobic and hydrophilic and surface tension were the basis to understand important principles such as Lotus Effect has introduced in workshop in details. The questions were:

i. "Su damlası bir zemin üzerinde yuvarlak şekilde duruyor. Bu zeminin özelliği hakkında ne söyleyebilirsiniz? - A water drop stays with its spherical shape on a surface. What can you tell about the properties of that surface?"

ii. "Bir tür kertenkele olan geckoların kirli bir yüzeyde yürürken ayaklarının kirlenmemesinin nedeni ne olabilir? - When a gecko, which is a type of a lizard, walks on a dirty surface, its feet keep clean. Why do you think that happens?"

iii. "Bir su örümceği su üzerinde yürüyerek dolaşabiliyor. Bunun nedenini açıklayabilir misiniz? - A water spider can walk on water. Can you explain the reason behind it?"

Before implementing this last version of the instrument, 2 colleagues and one expert from educational and chemistry research reviewed the items. Such review of the items and their face validity led to the deletion, modification and inclusion of new items before field-testing. The question format of Part one, Understanding of Nanoscience and Nanotechnology, changed to multiple-choice format. In Part two, two concepts had extracted from an initial twelve concepts that were to put in order, and to estimate their sizes. First version of scale administered one time to ten preservice teachers who were attending a science, technology and course.

An answer key with points assigned to each question's answers prepared by the researcher. Each participant's answers had evaluated and scores taken from three parts separately and total score were calculated. Colleagues and experts to increase the inter-rater reliability also reviewed the answer key and the points to answers.

3.7.3. Nanoscience and Nanotechnology Workshop Evaluation Questionnaire (NNWEQ)

"Nanoscience and Nanotechnology Workshop Evaluation Questionnaire" contained twelve open-ended questions (See Appendix C). These questions measured participants' ideas and opinions about the components of the workshop. First component was the workshop itself. The purpose of the questions related to workshop itself was to learn participants' views about workshop. The questions asked the most/least informative part, the most/least impressive thing, the most/least enjoyable part. In addition, students were asked to list three things to keep/omit in the workshop. There were also questions about other components of the workshop. These components were "the project leader" and the "mentor of the group". Students asked to state any suggestions for improvement of the workshop. In addition, students were asked whether they would participate in another workshop in the future.

After completing the analysis of the evaluation form, a general view of students about the workshop obtained. Any recommendation and suggestion came from students were taken into consideration for other implementations of the workshop. Students' perspectives, opinions and needs should be taken seriously to develop a more effective, interesting and enjoyable workshop in the future.

3.7.4. Pre Interview Questions of Nanoscience and Nanotechnology Workshop

In order to explore students' previous knowledge, understanding and expectations from workshop, the researcher conducted a structured interview with twelve questions (See Appendix J). Each interview almost took 10-15 minutes long. Each one-by-one interview audio recorded.

The questions were adapted from Akaygün's (2010a, b) study. The questions formed parallel to the Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ) and Nanoscience and Nanotechnology Conceptual Understanding Questionnaire (NNCUQ). The parallel questions allowed researcher to determine whether students are consistent with their answers. Colleagues and experts for clarifications and completeness revised the questions.

Researcher asked students to describe themselves briefly. Then students were asked to state the field of work they want to choose in the future. In relation to nanoscience and nanotechnology, students explained if they heard nanoscience and nanotechnology terms before or not. If the responses were yes, the researcher wanted students to state where they saw these words before and what these words mean to them. Researcher wanted students to explain what they have already known in details and if they have heard about any recent nanotechnology research. Then, nanoscientific terms: nano particles, carbon nanotubes, scanning tunneling microscopes (STM) and Atomic Force Microscopes (AFM) were told to students and asked if they sound familiar to them. After this question, students were asked to give some examples to possible risks and benefits of nanoscience and nanotechnology bring. Add to this, researcher wanted students to consider themselves as a citizen and told if they saw themselves as a scientifically literate person in terms of nanoscience and nanotechnology. Students were asked to state the nanoscience and technology related thing that they are most curious about and have desire to learn. Researcher also asked if students would like to attend nanoscience and nanotechnology related lesson in school. Since this interview conducted before the workshop, researcher told students to mention their expectations from workshop and if they were voluntarily attend the workshop or not. The interview ended with by asking students whether they wanted to ask or to add something or not.

3.7.5. Post Interview Questions of Nanoscience and Nanotechnology Workshop

The post interviews were conducted 3-4 weeks after workshop implementations. The interview questions included pre interview questions and some of the NNWEQ questions in it. This enabled the researcher to make comparisons. According to results of this comparison, the effect of workshop on students' understanding and awareness were obtained. Addition to these questions, students were also asked whether attending this workshop increased their understanding of nano related concepts or not. Students were asked to explain their thoughts. Related to workshop, students were asked to state which concepts they had difficulty to understand the most and the least. Add to this, the researcher wanted students to state the most informative part of the workshop and also the most impressive thing they learned during workshop. It was also asked if workshop had an effect on changing students' personal opinions about nanoscience and nanotechnology or not. In addition, students were asked if they could find answers to their questions about the thing that they were most curious about. Researcher also asked if the workshop met students' expectations or not. Add to this, students were asked if they did a research about nanoscience nanotechnology after the workshop. Similar to NNWEQ questions, students were asked to state the things they suggest to omit/stay/add to workshop content. Researcher also asked if students would like to attend a new workshop developed about nanoscience and nanotechnology. The interview ended with by asking students whether they wanted to ask or add something or not.

The timeline of data collection was summarized in Table 3.4

Table 3.4. The timeline of data collection.

Data Sources	Date of Data Collection			
	Pr1	Pr2	Pu1	Pu2
Pre-NNAQ	22.12.2010	29.12.2010	14.01.2011	14.01.2011
Pre-NNCUQ	22.12.2010	29.12.2010	14.01.2011	14.01.2011
Pre Interviews	22.12.2010	29.12.2010	14.01.2011	14.01.2011
Post-NNAQ	25.12.2010	03.01.2011	19.01.2011	20.01.2011
Post-NNCUQ	25.12.2010	03.01.2011	19.01.2011	20.01.2011
NNWEQ	25.12.2010	03.01.2011	19.01.2011	20.01.2011
Post Interviews	26.01.2011	24.01.2011	04.03.2011	04.03.2011

3.8. Procedure

As it was stated before, this workshop was implemented with three different schools in the physics laboratory of Department of Secondary School Science and Mathematics Education in Bogazici University. Two of the participating schools were private schools; the other one was a public school. From that public school two different classrooms of the same grade level attended to workshop in different times. Therefore, there were four implementations, two of them with private school (Pr1 and Pr2) and two of them with public school (Pu1 and Pu2). In this procedure section, each implementation with these three different schools was explained. Before these four implementations, one pilot implementation was done with 10 prospective teachers who were taking a science, technology and society course.

3.8.1. Mentor Training Meetings

Mentors were the integral part of this study. There were 17 mentors who were voluntarily took part in NNW. Ten of them were senior students and seven of them were junior students who were prospective teachers studying at Bogazici University. Majority of these students had also voluntarily participated in Akaygün's (2010a, b) study, which was about design and implementation of a nanotechnology workshop, which took place in the

ILKYAR organizations done in 2010 and 2011. In that organization, school teachers were the participants of the workshop. For the organization of NNW, researcher contacted with prospective teachers via email. It was asked whether they preferred to participate in NNW. According the responses taken, an email group called "nano group" was created for these volunteer prospective teachers. They called mentors during the NNW. Fourteen meetings were organized with mentors. At the beginning, it was difficult to adjust a common meeting time. It was decided that to have the meetings after school. In the first two meetings, the mentors from ILKYAR organization were attended. They were asked to invite their friends to join the group.

During the meetings, role of the mentors, content of the NNW and any organization details such as arranging schools were discussed. The content of the activity; including activities, presentations, worksheets, materials were revised and formed. Before the implementations, activity stations were prepared, materials were checked and each activity was tried by the mentors to avoid any mistakes. Researcher offered reading materials to the mentors to enhance their understanding about nanoscience and nanotechnology. The timeline of the mentor training meetings summarized in Table 3.5.

In NNW, mentors took different responsibilities. Participants for NNW were divided into six groups, and two mentors coordinated each group. The other mentors shared different responsibilities which were; welcoming participants, taking photographs, recording videos, controlling the computer during the presentations, arranging the materials, assisting group mentors, taking participants to a campus tour. After each implementation, mentors were gathered together in order to review the day. According to the collected suggestions, some revisions were done for the following implementations.

Table 3.5. The timeline of the mentor training meetings.

Number of Meetings	Date of the Meeting	Content of the Meeting
1	18.10.2010	General introduction
2	27.10.2010	General introduction cont. Sharing ideas about the organization of NNW

Table 3.5. The timeline of the mentor training meetings cont.

Number of Meetings	Date of the Meeting	Content of the Meeting
3	3.11.2010	New members joined to the group. Discussion about the content of NNW
4	10.11.2010	Introduction of the activities by the researcher. Discussion about the materials needed
5	29.11.2010	Materials for each activity stations were prepared. Each of the activity was tried by mentors.
Pilot Implementation with Prospective Teachers - 30.11.2010		
6	13.12.2010	Evaluation about the pilot implementation was done. Suggestions for revisions for the following implementations made by the mentors.
7	20.12.2010	Revisions of activities were done by the researcher.
8	22.12.2010	Revised activities were reviewed by the mentors. Possible questions come from students were discussed.
9	23.12.2010	Materials for each activity stations were prepared. Each of the activity was tried by mentors.
First Implementation: Pr1 - 24.12.2010		
10	29.12.2010	Evaluation about the first implementation was done. Suggestions for revisions for the following implementations made by the mentors.
11	02.01.2011	Materials for each activity stations were prepared.
Second Implementation: Pr2 - 03.01.2011		
12	18.01.2011	Evaluation about the second implementation was done. Suggestions for revisions for the following implementations made by the mentors.
Third Implementation: Pu1 - 19.01.2011		
13	19.01.2011	Evaluation about the third implementation was done. Suggestions for revisions for the following implementations made by the mentors.
Fourth Implementation: Pu1 - 20.01.2011		
14	20.01.2011	Evaluation about the fourth implementation was done

3.8.2. Pilot Implementation with Prospective Teachers

Only 10 prospective teachers attended to workshop. The course duration was two lesson hours, which was too short to cover all workshops content. Researcher planned to cover only two hours of the actual workshop and see if time planning went smoothly and if the introduction presentation and first two activities were clear to students. It was planned to see the weaknesses and missing points in the workshop before real implementations with high school students. In addition, prospective teachers' responses obtained by NNWEQ taken seriously and missing points tried to be completed before the first implementation. In this first trial, individual activity papers were not completely organized yet. For instance, in pilot testing there were five activities rather than four. First "cutting into nanoscale activity" and the second "black box activity" were almost the same. In the second activity, there was an extra group prediction part before the activity. This part omitted in the following implementation. Some key questions transferred to individual activity paper. There were too many questions follow the observation part, unnecessary ones omitted. Third activity was completely different from the first and the latest version of school implementations. Third activity consisted of two separate missions. First activity called as "Create your own waterproof fabric". In this activity, cotton fabrics and some materials such as wax, crayons, seed, lanolin, clay, and glue were given to students. Students were asked to devise a way to "waterproof" a piece of fabric. Afterwards, they were asked to answer some questions according to their observations. The main idea of this activity was to make students work in group to develop a waterproof material and compare their results with nano water proof materials developed by scientists. This activity was adapted from a lesson plan called "Nano Waterproofing" provided by tryNano.org. The second mission called "Any Stains Left?" In this activity, students tested a nano fabric, one normal cotton fabric and a semi synthetic fabric. They used different liquids such as juice, coke, vinegar and oil. In addition, they used different solids such as ketchup, mayonnaise, mustard and an organic soil. Using a pipette place a droplet of each liquid on each tested fabric. After some time, students removed the liquids with a paper towel and wrote their observations. The main idea of this activity was to make students compare their results with nano stain resistant materials developed by scientists. Also to show as other examples to nano applications, some nano-coated materials such as a t-shirt, a stone and a piece of paper tissue have shown to students. Lotus Effect, which designed as a separate activity, could not be done due to time limitation.

As evaluation of the workshop, preservice teachers mentioned that, there were too many questions in the second activity and they did not make a conclusion about the third activity. In addition, the researcher examined the answer sheets of groups and realized that, individual and group conclusions were almost missing in each group's activity paper. This was an important point to put emphasis on for the next implementations.

3.8.3. First Implementation: Pr1

From Pr1, 28 of 11th grade students were supposed to be the sample. However, workshop day 10 students were missing. Overall, participant number for the first implementation was 18. The researcher contacted to head of science department of the Pr1, who was also a chemistry teacher almost a month ago before the implementation. Date and time were arranged accordingly. A biology teacher and a physics teacher were also at workshop only as observers.

The researcher coordinated the implementation. During the implementation students worked in 6 groups and each group has one mentor who was a prospective teacher from Department of Secondary School Science and Mathematics Education, at Bogazici University. The pilot test for the NNAQ was also done at Pr1. Pre-NNAQ, Pre-NNCUQ and pre interview also used at Pr1 one week before the implementation. The flow of the process in details given as:

3.8.3.1. Contact with Pr1 (December 12, 2010). The researcher sent an email with attachments of the work plan, the brochure (See Appendix K) and the poster of the workshop to the head of department of Pr1. A meeting appointment arranged and head of department visited Bogazici University and got more information about the workshop and the study aspect of it. The dates and time for pilot test of awareness and conceptual understanding questionnaires, pre-awareness and pre-conceptual understanding questionnaires and pre- interviews, workshops were set.

3.8.3.2. Pilot testing of Awareness and Conceptual Understanding Questionnaires (December 21, 2010). Awareness and Conceptual Understanding Questionnaires were given to 50 students from 10th grade.

3.8.3.3. Pre-visit to (December, 22, 2010). Pre-awareness and pre-conceptual understanding questionnaires were given to students. Also, the researcher conducted one-by-one pre interview that takes not more than 10 minutes. The head of department selected students.

3.8.3.4. First workshop day (December, 25, 2010). Morning session: Students had arrived Bogazici University in the morning and they took their designated place in the laboratory and met with their group mentors. After a brief welcoming, the researcher made the introductory PowerPoint presentation, (Appendix D) that included a short scale activity and ferrofluid demonstration. After the presentation, the researcher introduced Activity 1 and Activity 2. According to the revisions made after the pilot study, each activity designed to have two kinds of activity worksheets (See Appendix E). One was “individual activity sheet” and the other is “group activity sheet”. Before each activity, “individual activity sheet” given to each student, then whole group worked on “group activity sheet”. In each activity, one group member assigned to note group decisions on “group activity sheet”. Activity 2 ended with an explanation PowerPoint presentation that includes some videos of Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy. After that presentation, there was a one-hour break time.

Afternoon session: After lunch break, afternoon session started with Activity 3. Since pilot study suggestions for the improvement of workshop were taken into consideration, Activity 3 was revised. Addition to mission one and mission two in Activity three, mission three was added. This mission was called Nano-coating test. In this activity, students drop water on a nano-coated stone, fabric and a paper tissue and made observations. The purpose was to make students comparisons of nano-coated materials and nano-manufactured materials. In addition, format of the activity completely changed. It was noted from the previous experience that, the activity sheet should not include so much question and students should note their observations in tables. In mission two, “Any Stains Left?” the number of materials used was reduced to three materials, which are juice, ketchup and muddy water. A presentation that introduces nanotechnology in the field of textile was shown to students. The subject of “textile” was chosen, because it is a daily life example that attracted attention. Also, nano fabrics and nano-coated fabrics were more available than other type of nanotechnology products. After students completed to fill in both individual and group conclusions, Activity 4 was introduced. This activity was “Solving the Mystery of Lotus Effect” that observations were made with on two different types of leaves and their surface properties. First observation was about to observe the shape of water droplets on different leaves. Second observation was about self-cleaning property. These two observations were followed by “contact angle measurement” demonstration and a presentation that introduces the concepts of “hydrophobic and hydrophilic surfaces”, their relations to “contact angle”, “intermolecular forces” and “surface tension”, “lotus effect”, “self-cleaning property". After that, Activity 5 was introduced to students as a discussion activity, which was about “Risks and Benefits of Nanotechnology”. This time, an introduction presentation had shown to students before group discussions. In this presentation, some of risks and benefits of nanotechnology shared with students to give them some ideas. After presentation, each group listed risks and benefits they decided on. It continued with sharing ideas with other groups. As the last activity, each group was asked to design a nano product. In the production process, students were told that they should state a name for a product, state what this product is about with details, draw a visual that represents the product and explain how it works and find a slogan for it. Groups presented their product to other groups. It was the end of the activities. Students introduced BU NANO facebook group, their emails were collected to add them in-group by the researcher. Post-NNAQ and post-NNCUQ were distributed.

3.8.3.5. <u>Follow up activity (January, 2, 2011).</u> Students were found on facebook and were sent invitations to join to BU Nano group. Twelve students out 18 added to the group. Although it was told students that they could share any news about nanoscience and nanotechnology, none of the students post anything. But, some of the students follow the posts that were done by the researcher and mentors.

3.8.3.6. Post-visit (January, 26, 2011). The researcher conducted one-by-one post interviews that took not more than 10 minutes. Three of the students were also attend pre-interviews. Researcher selected other two students according to their pre and post NNAQ results.

3.8.4. Second Implementation: Pr2

The number of students attended to workshop from Pr2 was 19 (6 of them were 12th graders). Although the intended sample was limited to 11th graders, 6 of 12th grade students were included in the study, because the researcher had to meet the request of schools that were voluntarily attending this one-day workshop. The researcher contacted to chemistry teacher of the Pr2 almost a month ago before the implementation. Date and time were arranged accordingly. The chemistry teacher and a physics teacher were also at workshop only as observers.

The researcher coordinated the implementation. The action flow of one-day workshop was same as first implementation with Pr1. Also, during the implementation students worked in 6 groups that consisted of 3 to 5 students and each group has one mentor who was a prospective teacher from Department of Science and Mathematics Bogazici University. The pilot test for the NNAQ was done at Pr2. Pre-NNAQ, pre-NNCUQ and pre interviews also implemented at Pr2 one week before the implementation. The flow of the process in details given as:

3.8.4.1. Contact with Pr2 (December 22, 2010). The researcher sent an email with attachments of the work plan, the brochure and the poster of the workshop to the chemistry teacher of Pr2. The dates and time for pre test of awareness and conceptual understanding questionnaires, pre- interviews and actual workshop date and time were set.

3.8.4.2. Pre-visit (December, 29, 2010). Pre-awareness and pre-conceptual understanding questionnaires were given to students. Also, the researcher conducted one-by-one pre interview that takes not more than 10 minutes. The chemistry teacher selected students. Interviews were done during a lesson hour.

3.8.4.3. Second workshop day (January, 3, 2011). Morning session: Students has arrived Bogazici in the morning and they took their designated place in the laboratory and met with their group mentors. The content of the workshop was almost same as the previous program of Pr1. There were few changes and additions in activities. These changes are explained below in order.

After a brief welcoming, the researcher made the introductory PowerPoint presentation that includes a short scale activity and ferrofluid demonstration. After the presentation (See Appendix D), Activity 1 and Activity 2 were introduced. Until this point, everything was similar to the previous implementation. Two interviews about Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) from R&D laboratory of Bogazici University were added to PowerPoint presentation of Activity 2. After that presentation, a one-hour lunch break was given.

Afternoon session: Afternoon session started with Activity 3. According to the suggestions from the first implementation for the improvement of workshop, Activity 3 has revised one more time. It was obvious that, the order of the activities missions involved in Activity 3 was confusing for the students. In design process of the activities, researcher thought that it would be better to start from a daily life example of application of nanotechnology, which is nano textiles and nano-coating, then seeking answer for the principles behind these applications, which is lotus effect. However, the suggestions of students and group mentors and the observation of researcher lead to need for one more revise in Activity 3. Respect to this, Activity 3 started with observations of water repellent leaves then continues with observations on different types of fabrics which were cotton, synthetic, nano and nano-coated fabrics. These two observations followed by “contact angle measurement” demonstration and a presentation that introduces the concepts of “hydrophobic and hydrophilic surfaces”, their relations to “contact angle”, “intermolecular forces”, “surface tension” and “lotus effect”. After that, students continued with “self-cleaning property” test. This observation followed by explanation of self-cleaning property and its relation to Lotus effect. Presentation also introduced nanotechnology in the field of textile and nano-coating. Biomimetics part which was also added after the first implementation was shown. After students completed to fill in both individual and group conclusions, Activity 4 was introduced. Since Lotus Effect included in Activity 3, Activity

4 replaced with Activity 5, which was a discussion activity about "Risks and Benefits of Nanotechnology". This time, whole class separated into two big groups. In other words, three groups combined and formed one big group; the rest three groups combined and formed another group. One group was assigned to list the risks of nanotechnology; the other group was assigned to list the benefits of nanotechnology. When the group works completed, groups shared their opinions and reach to a consensus. This discussion part followed by a short conclusion presentation that summarizes some of the risks and benefits of nanotechnology as the last activity, each group was asked to design a nano product. There was no revision on this activity, so it was similar to the one in first implementation. Nano related product design was followed by group presentations. It was the end of the activities. Students introduced BU NANO facebook group, their emails were collected to add them in-group by the researcher. Post-NNAQ and post-NNCUQ were distributed.

3.8.4.4. Follow up activity (January, 9, 2011). Students were found on facebook and were sent invitations to join to BU Nano group. Thirteen students out 18 added to the group. Although it was told students that they could share any news about nanoscience and nanotechnology, none of the students post anything.

3.8.4.5. Post-visit (January, 24, 2011). The researcher conducted one-by-one post interviews with 7 students that took not more than 10 minutes. Two of the students also attended pre-interviews. Researcher selected other five students according to their pre and post Awareness Questionnaire results.

3.8.5. Third Implementation: Pu1

The number of students attended to workshop from Pu1 was 19. The researcher contacted to chemistry teacher of the Pu1 almost a month ago before the implementation. The chemistry teacher suggested attending the workshop with two classes in separate days. Date and time were arranged accordingly. The chemistry teacher and a physics teacher were also at workshop only as observers.

The researcher conducted the implementation. The action flow of one-day workshop was same as previous implementations done with Pr1 and Pr2. The flow of the process in details given as:

3.8.5.1. Contact with Pu1 (December, 22, 2010). The researcher sent an email with attachments of the work plan, the brochure and the poster of the workshop to the chemistry teacher of Pu1. The dates and time for pre test of awareness and conceptual understanding questionnaires, pre- interviews and actual workshop date and time were set.

3.8.5.2. Pre-visit to Pu1 (January, 14, 2010). Pre-awareness and pre-conceptual understanding questionnaires were given to students. In addition, the researcher conducted one-by-one pre interview that takes not more than 10 minutes. The chemistry teacher selected students. Interviews were done during a lesson hour.

3.8.5.3. Third workshop day (January, 19, 2011). Morning session: Students arrived in Bogazici University in the morning and they took their designated place in the laboratory and met with their group mentors. The content of the workshop was almost same as the previous program of Pr1 and Pr2. There were only few changes in activities.

After a brief welcoming, the researcher made the introductory PowerPoint presentation (See Appendix D). After the presentation, Activity 1 and Activity 2 were introduced. PowerPoint presentation of Activity 2 had some revisions. Two interviews about Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) from R&D laboratory of Bogazici University were edited and got shortened. Because, the results of previous implementation’s workshop evaluation showed that the interview videos were too long. After that presentation, a one-hour lunch break was given.

Afternoon session: Afternoon session started with Activity 3. This time, no revision needed and activity was done in the same order. Activity 3 started with “water repellent surface” test, which starts with observations on leaves then continues with observations on different types of fabrics. These two observations followed by “contact angle measurement” demonstration and a presentation that introduces the concepts of “hydrophobic and hydrophilic surfaces”, their relations to “contact angle”, “intermolecular forces", "surface tension" and "lotus effect". After that, students continued with "self-cleaning property" test. This observation followed by explanation of self-cleaning property and its relation to Lotus effect. Presentation also introduced nanotechnology in the field of textile and nano-coating and some examples of biomimetics. The Activity 4, discussion activity about "Risks and Benefits of Nanotechnology" was introduced. Similar to the first implementation, each group work in their smalls group and discuss and list both risks and benefits of nanotechnology. When the group works completed, groups shared their opinions with other groups. As the last activity, each group was asked to design a nano product. There was no revision on this activity too. Nano related product design followed by group presentations. It was the end of the activities. Students introduced BU NANO facebook group, their emails were collected to add them in-group by the researcher. Post-NNAQ and post-NNCUQ were distributed.

3.8.5.4. Follow up activity (January, 23, 2011). Students were searched on facebook according to their names. Nevertheless, researcher could not easily found most of the students on facebook, since there was many research results show up for same name so that invitations could not send to students from Pu1. Although it was told students that they could also find the BU NANO group on facebook and be a member of it, no one join the group by themselves. However, the chemistry teacher of the Pu1 also mentioned that when BU NANO name was searched, she also could not find the group. Because of this technical problem, facebook group did not function as it was planned.

3.8.5.5. Post-visit (March, 1st week, 2011). The researcher conducted one-by-one post interviews with students that took not more than 10 minutes. The date arranged according to the program of chemistry teacher in Pu1.

3.8.6. Fourth Implementation: Pu2.

The number of students attended to workshop from public Pu2 was 25. Only the chemistry teacher attended at workshop as observer.

The researcher coordinated the implementation. The action flow of one-day workshop was same as previous implementations done with Pr1, Pr2 and Pu1. Since Pu2 is the other class of Pu1, arrangement of date and time, pre visit to school including pre-awareness and pre-conceptual understanding questionnaires and pre- interviews were done on the same day with Pu1.

3.8.6.1. Fourth workshop day (January, 20, 2011). The flow of the process was same as the previous third implementation. During morning and the afternoon, the Activity 1/2/3 and Activity 5 were done in the same order with the same content. Only Activity 4 was differ than the implementation of Pu1, but similar to the implementation of Pr2. The idea behind this difference was to decide which way was more effective in terms of students' active participation. Post-NNAQ and post-NNCUQ were distributed.

The follow up situation was also same for Pu2 as Pu1 since they represent two classrooms of the same school, Pu1. Moreover, post visit to Pu2 was done on the same day with Pu1.

The timeline of implementations is summarized in Table 3.6.

Table 3.6. The timeline of nanoscience and nanotechnology workshop (NNW).

	1st NNW Pr1	2nd NNWPr2	3rd NNW Pu1	4th NNW Pu2
Contact with Schools	12.12. 2010	22.12. 2010	22.12. 2010	22.12. 2010
Pre-visit	22.12. 2010	29.12. 2010	14.01. 2011	14.01. 2011
NNW	25.12. 2010	03.01. 2011	19.01. 2011	20.01. 2011
Follow-up	02.01. 2011	09.01. 2011	23.01. 2011	23.01. 2011
Post-visit	26.01. 2011	24.01. 2011	04.03. 2011	04.03. 2011

4. DATA ANALYSIS AND RESULTS

This section includes statistical analysis of three research questions. Depending on the nature of the questions, qualitative and quantitative analysis were done. The first question was "Will there be any change in 11^{th} grade students' awareness of nanoscience and nanotechnology after attending NNW?" This question tested whether there is any difference or not in students' awareness of the aspects of nanoscience and nanotechnology. The second research question was "Will there be any change in 11^{th} grade students' conceptual understanding of nanoscience and nanotechnology after attending NNW?" This question tested whether there is a progression or not in conceptual understanding of the aspects of nanoscience and nanotechnology. The first two research questions involve the statistical analysis of different comparisons across the groups. The comparisons are for "all participants", "private versus public schools", "Participants with respect to their groups". The third research question was "What are the outcomes obtained from student generated products as result of attending NNW?" This question tested to obtain detailed information about students' awareness and understanding of the aspects of nanoscience and nanotechnology. "2^{nd} question of NNCUQ", "group discussion of benefits and risks of nanoscience and nanotechnology", "designing a nano product poster activity", "evaluation of NNW" and "interviews" were analyzed to answer third question.

4.1. Statistical Analysis of Research Question 1

- Research Question-1: Will there be any change in 11th grade students' awareness of nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW)?

- Hypothesis 1: There will be a significant increase in 11^{th} grade students' awareness of nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW).

- Null hypothesis 1: There will be no significant increase in 11th grade students' awareness of nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW).

Four different classes from three different schools participated in this study. These four classes included two classes from two different private high schools (Pr1 & Pr2) and two classrooms from one public high school (Pu1 & Pu2).

Null hypothesis 1 was tested based on three different comparisons between these participating classes. The sample group comparisons were done as follows:

- Comparison 1: All the students were considered as one single group, and NNAQ-pre and NNAQ-post scores were compared. Whole sample was used for evaluating NNW's effect on students' nanoscience and nanotechnology awareness.

- Comparison 2: Public and private schools were compared with respect to their NNAQ-pre and NNAQ-post scores. Two classes from the public high school were compared with the two classes from the private schools to evaluate if any differences among public and private schools.

- Comparison 3: Four groups were compared separately to evaluate the effect of NNW on nanoscience and nanotechnology awareness of students in different classes.

The data analysis of NNAQ for each group comparison is given below.

4.1.1. Comparison of All Participants

To analyze the effect of workshop on the awareness of 79 participants, a one-way analysis of variance (ANOVA) was conducted to compare the effect of school background on nanoscience and nanotechnology awareness in terms of NNAQ-pre test. "ANOVA is a parametric test of significance used to test for a difference between two or more means at a selected probability level" (Gay *et.al.,* 2006, p. 606). Before grouping all the participants as one large group, the classes were compared with respect to their prior awareness of nanoscience and nanotechnology.

Table 4.1. Descriptive statistics about NNAQ-pre scores for each student groups.

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
NNAQ-pre	1	18	40.78	16.254	3.831	21	78
	2	19	41.11	8.353	1.916	23	56
	3	17	34.65	14.709	3.568	20	70
	4	25	43.08	11.431	2.286	25	72
	Total	79	40.27	12.958	1.458	20	78

Table 4.2. One-way ANOVA results on NNAQ-pre scores for student groups.

		Sum of Squares	df	Mean Square	F	Sig.
NNAQ- pre	Between Groups	752,795	3	250.932	1.525	.215
	Within Groups	12344.623	75	164.595		
	Total	13097.418	78			

ANOVA test results showed that there was no significant effect of school background on pre-test scores of NNAQ at the < .05 levels for the conditions, hence all the groups were considered as one large sample for the first comparison.

Since, NNAQ-pre test scores of student groups did not significantly differ from each other, all participants were also considered as one group and paired samples t-test was applied. Paired samples t-test was applied to compare nanoscience and nanotechnology awareness in NNAQ-pre- and NNAQ-post scores. Paired difference of NNAQ-pre- and NNAQ-post scores was calculated. There are 20 items and the total score of the test is 100. As alpha (2-tailed) value shows, NNAQ-pre and NNAQ-post scores on NNAQ differed significantly (p=. 000).

Table 4.3. Descriptive statistics about comparing NNAQ-pre and NNAQ-post nanoscience and nanotechnology awareness scores for all students.

	N	Mean	Std. Deviation
NNAQ- pre	79	40.2658	12.95823
NNAQ- post	79	83.6456	10.41330

As shown in Table 4.3, the mean scores of students in the NNAQ-pre was M=40.2658 and the standard deviation for scores was SD= 12.95823. The mean of the scores showed an increase in the NNAQ-post scores of participants; it was found to be M=83.6456 and SD=10.41330.

Table 4.4. Results of paired samples t-test for comparing NNAQ-pre and NNAQ-post mean scores of all students.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
NNAQ-pre and NNAQ-post scores	-25.609	78	.000	43.380	1.694

As a result of the analysis, the difference between NNAQ-pre scores (M=40.2658, SD= 12.95823) and NNAQ-post scores (M=83.6456 and SD=10.41330) of students were found to be significantly different t(78) = -25.609, p=0.000 (See Table 4.4). Paired samples t-test concluded that NNAQ-pre and NNAQ-post scores of all students differed significantly confirming an increase in the NNAQ-post scores; hence the nanoscience and nanotechnology awareness.

4.1.2. Comparison with Respect to School Types (Private versus Public Schools)

To compare private schools with public schools in terms of their NNAQ-pre and NNAQ-post scores, two classes from the public school were taken as one group (Public) and two private schools were taken as another group (Private). Independent samples t–test was carried out to compare NNAQ-pre and NNAQ-post scores.

Table 4.5. Descriptive statistics about comparing NNAQ-pre and NNAQ-post scores of public and private school students.

School	N	Mean	Std. Deviation
NNAQ- Pre Private	37	40.9459	12.63581
NNAQ- Pre Public	42	39.666	13.35932
NNAQ- Post Private	37	81.0541	11.59728
NNAQ- Post Public	42	85.9286	8.76354

As shown in Table 4.5, the mean of score of the private schools in the NNAQ-pre was M=40.9459 and the mean of scores of the public schools in the NNAQ-pre was M= 39.6667. The standard deviation of scores of the private schools in the NNAQ-pre was SD= 12.63581 and the standard deviation of scores of the public schools in the NNAQ-pre was SD= 13.35932. The mean of NNAQ-post scores was found to be M=81.0541 for the private schools and M=85.9286 for the public schools. The standard deviation of scores in the post-test were SD= 11.59728 and SD=8.76354

In order to determine whether there was a significant difference between the NNAQ-pre mean scores of private and public schools, independent samples t-test was used. " t test for independent samples is a parametric test of significance used to determine whether, at a selected probability level, a significant difference exists between the means of two independent samples" (Gay *et.al.,* 2006, p. 335) The significant difference between NNAQ-post means scores of private and public schools were also compared by independent samples t-test shown in Table 4.6.

Table 4.6. Results of independent samples t-test comparing NNAQ-pre and NNAQ-post mean scores of students in the public schools.

School	F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
Private NNAQ- Pre-Public	.018	.893	.436	77	.664	1.27928	2.93698
			.437	76.594	.663	1.27928	2.92653
Private NNAQ- Post-Public	2.320	.132	- 2.122	77	.037	-4.87452	2.29686
			-2.085	66.543	.041	-4.87452	2.33744

As a result of the independent samples t-test analysis, there was no significant difference in the NNAQ-pre test results for the private (M=40.9459, SD=12.658) and public (M=39.666, SD=13.35932), t (77) =0.436, p=. 664. On the other hand, NNAQ-post mean scores of private and public schools showed significant difference for the private (M=81.0541, SD=11.59728) and public (M=85.9286, SD=8.76354), t (77)=-2.122, p= .037.

The other analysis was done for private school group and public school group separately. Paired samples t-test was used to compare NNAQ-pre and NNAQ-post mean scores of private school students. Paired samples t-test was conducted for private schools resulted as there was a significant difference in the scores for NNAQ-pre (M=40.95, SD= 12.636) and NNAQ-post tests (M=81.05, SD=11.597) of private schools; t (36) = -15.543, p= .000 (See Table 4.7).

Table 4.7. Results of paired samples t-test comparing NNAQ-pre and NNAQ-post mean scores of private school students.

	Paired Differences					t	df	Sig. (2-tailed)
Private school group	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
NNAQ–pre NNAQ-post	-40.108	15.696	2.580	-45.342	-34.875	-15.543	36	.000

These results suggested that NNW did have a positive effect on awareness of nanoscience and nanotechnology for private schools, since the NNAQ-post scores were significantly higher than NNAQ-pre scores of the participants of private schools.

Paired samples t-test was also used to compare NNAQ-pre and NNAQ-post mean scores of public school students. “The paired samples t-test is used to compare a single group’s performance on a pre and post-test, or on two different treatments” (Gay *et.al.,* 2006, p. 354). Therefore, paired samples t-test conducted for public schools revealed that there was a significant difference in the scores for NNAQ-pre (M=39.67, SD= 13.359) and NNAQ-post tests (M=85.93, SD=8.764) of public schools; t(41) = -21.375, p= .000 (See Table 4.8).

Table 4.8. Results of paired samples t-test comparing NNAQ-pre and NNAQ-post mean scores of students in the public schools.

	Paired Differences					t	df	Sig. (2-tailed)
Public school group	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
NNAQ–pre NNAQ-post	-46.262	14.026	2.164	-50.633	-41.891	-21.375	41	.000

The difference in NNAQ-pre and NNAQ-post mean scores of each group who differed in terms of their school background was further analyzed using nonparametric sign test and descriptive statistics. Nonparametric test was used to determine if there was a significant difference between NNAQ-pre and NNAQ-post test scores for each student group. The nonparametric tests were used since sample size of each group was small. Descriptive statistics and sign test statistics for each school are given in the section below.

4.1.3. Comparison of Participants with Respect to Their Groups

4.1.3.1. Private School 1 (Pr1). 18 students from Pr1 who took NNAQ-pre attended workshop and they also took NNAQ-post at the end of the workshop.

Nonparametric sign test was conducted. The difference between pre and post test scores obtained from Nanoscience and Nanotechnology Awareness Questionnaire (NNAQ) was analyzed by nonparametric sign test.

Exact significance (2-tailed) value was calculated for each group one by one. Results showed that there was a significant (p=.000) difference between NNAQ-pre and NNAQ-post score of each group within itself.

Table 4.7. Descriptive and sign test statistics for NNAQ scores of participants from Pr1.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNAQ-Pre	18	40.78	16.254	21	78	.000
NNAQ-Post-	18	86.50	9.173	66	99	

As shown in Table 4.7, the mean of scores of the students in NNAQ-pre was M=40.78 and the standard deviation of the scores is SD= 16.254. The mean of the scores showed an increase in NNAQ-post and it was found to be M=86.50 and SD=9.173.

4.1.3.2. Private School 2 (Pr2). 19 students from Pr2 who took NNAQ-pre attended workshop.

Exact significance (2-tailed) value was calculated for each school showed that there was a significant (p=.000) difference between NNAQ-pre and NNAQ-post scores of Pr2.

Table 4.8. Descriptive statistics for NNAQ scores of participants from Pr2.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNAQ- Pre	19	41.11	8.353	23	56	
NNAQ-Post	19	75.89	11.479	48	94	.000

The mean of scores of the students in the NNAQ-pre was M=41.11 and the standard deviation of the scores was SD= 8.353. Therefore, the mean of the scores showed an increase in the NNAQ-post and it was found to be M=75.89 and SD=11.479 as seen in Table 4.10.

Nonparametric sign test was carried out to determine whether the difference between NNAQ-pre and NNAQ-post scores were statistically significant or not. It was found that there was a statistically significant difference (p=.000) between NNAQ-pre and NNAQ-post scores of participants of Pr2.

4.1.3.3. Public School 1 (Pu1). Seventeen students from Pu1 who took NNAQ-pre attended workshop also took NNAQ-post at the end of the NNW. Exact significance (2-tailed) value was calculated for Pu1 showed that there was a significant (p=.000) difference between NNAQ-pre and NNAQ-post scores of Pu1.

Table 4.9. Descriptive statistics for NNAQ scores of participants from Pu1.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNAQ-pre	17	34.65	14.709	20	70	.000
NNAQ-post	17	87.94	10.437	66	99	

As shown in Table 4.9, the mean of scores of the students in NNAQ-pre was M=34.65 and the standard deviation of the scores was SD= 14.709. The mean of the scores showed an increase in the NNAQ-post scores of participants and calculated as M=87.94 and SD=10.437. It was found that there was a statistically significant difference between NNAQ-pre and NNAQ-post scores of participants' from Pu1.

4.1.3.4. Public School 2 (Pu2). Another class of 25 students from the same public high school who took NNAQ-pre before attending the workshop and took NNAQ-post after the workshop.

Exact significance (2-tailed) value was calculated also for this class, Pu2, and the results of the paired sample t-test showed that there was a significant (p=.000) difference between NNAQ-pre and NNAQ-post scores of Pu2.

Table 4.10. Descriptive statistics for NNAQ scores of participants from Pu2.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNAQ-pre	25	43.08	11.431	25	72	.000
NNAQ-post	25	84.56	7.332	70	95	

As shown in Table 4.10, the mean of scores of the students in NNAQ-pre was M=43.08 and the standard deviation of the scores was SD= 11.431. The mean of the scores showed an increase in the NNAQ-post scores of participants; they were found to be M=84.56 and SD=7.332.

It was also found that there was a statistically significant difference (p=.000) between NNAQ-pre and NNAQ-post scores of participants of Pu2.

4.2. Statistical Analysis of Research Question 2

- Research Question-2: Will there be any change in 11^{th} grade students' conceptual understanding about nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW)?

- Hypothesis 2: There will be a significant increase in conceptual understanding of nanoscience and nanotechnology of 11^{th} grade students who attended Nanoscience and Nanotechnology Workshop (NNW).

- Null Hypothesis 2: There will be no significant increase in conceptual understanding of nanoscience and nanotechnology of 11^{th} grade students who attended Nanoscience and Nanotechnology Workshop (NNW).

Similar to the data analysis of NNAQ three different sample groups were formed for data analysis to test null hypothesis 2.

4.2.1. Comparison of All Participants

To analyze the effect of workshop on the conceptual understanding of 79 participants, a one-way analysis of variance (ANOVA) was conducted to compare the effect of school background on nanoscience and nanotechnology awareness in terms of NNCUQ-pre test. Before grouping all the participants as one large group, the classes were compared with respect to their prior conceptual understanding of nanoscience and nanotechnology.

Table 4.11. Descriptive statistics about NNCUQ-pre scores for each student groups.

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
NNCUQ-pre	1	18	17,05	6,859	1,574	8	32
	2	19	15,22	5,128	1,209	5	25
	3	17	13,18	5,054	,828	5	23
	4	25	13,36	5,024	1,005	5	23
	Total	79	13,56	6,057	,681	5	32

Table 4.12. One-way ANOVA results on NNCUQ- pre scores for student groups.

		Sum of Squares	df	Mean Square	F	Sig.
NNCUQ-pre	Between Groups	775,205	3	258,402	0.317	.088
	Within Groups	2086,289	75	162.064		
	Total	2861,494	78			

ANOVA test results showed that there was no significant effect of school background on pre-test scores of NNCUQ at the < .05 levels for the conditions, hence all the groups were considered as one large sample for the first comparison. Since, NNCUQ-pre test scores of student groups did not significantly differ from each other, all participants were also considered as one group and paired samples t-test was applied. Paired samples t-test applied to compare nanoscience and nanotechnology conceptual understanding in NNCUQ-pre- and NNCUQ-post scores. Paired difference of NNCUQ-pre- and NNCUQ-post scores was calculated. NNCUQ-pre and NNCUQ-post scores on NNAQ differed significantly (p=.000). Descriptive statistics was carried out in order to compare all students' mean scores in the Questionnaire of Conceptual Understanding of Nanoscience and Nanotechnology given before (NNCUQ-pre) and after (NNCUQ-post) the workshop.

Table 4.13. Descriptive statistics comparing NNCUQ-pre and NNCUQ-post scores of all the students.

	N	Mean	Std. Deviation
NNCUQ-Pre	79	13.56	6.057
NNCUQ-Post	79	22.73	7.216

As shown in Table 4.13, the mean of score of the students in the NNAQ-pre was M=13.56 and the standard deviation for scores was SD= 6.057. The mean of the scores showed an increase in the NNAQ-post scores of participants; it was found to be M=22.73 and SD= 7.216. In order to determine whether the difference between the mean scores was significant or not, paired samples t-test was used.

Table 4.14. Results of paired samples t-test for comparing the NNCUQ-pre and NNCUQ-post mean scores of all students.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
NNCUQ-Pre NNCUQ-Post	-11.796	78	.000	-9.177	.778

As a result of the analysis, the difference between NNCUQ-pre scores (M= 13.56. SD= 6.057) and NNCUQ-post-test scores (M= 22.73 and SD= 7.216) of students were found to be statistically different (p=.000), t (78) = -11.79 (See Table 4.14). Both descriptive statistics and paired sample t-test concluded that NNCUQ-pre and NNCUQ-post scores of all students improved after attending the NNW.

4.2.2. Comparison with Respect to School types (Private versus Public Schools)

To compare private schools with public schools in terms of NNCUQ-pre and NNCUQ-post scores, two private schools were taken as one group (Private) and two public schools were taken as another group (Public). Group statistics for NNCUQ-pre and NNCUQ-post scores were calculated. Descriptive statistics and independent samples t-test were applied. Descriptive statistics was carried out in order to compare private school students' and public school students' mean scores of pre and post NNCUQ test scores.

Table 4.15. Descriptive statistics comparing NNCUQ-pre and NNCUQ-post scores of public and private school students.

School		N	Mean	Std. Deviation
NNCUQ- Pre	Private	37	16.16	6.067
	Public	42	11.26	5.095
NNCUQ- Post	Private	37	25.65	7.436
	Public	42	20.17	6.008

As shown in Table 4.15, the mean of score of the private schools in the NNCUQ-Pre was M= 16.16 and that of the public schools was M= 11.26 and the standard deviation of scores of the private schools in the NNCUQ-pre was SD= 6.067 and that of the public schools was SD= 5.095. The mean of NNCUQ-post scores was found M= 25.65 for the private schools, and M= 20.17 for the public schools. The standard deviation of scores in the post-test were SD= 7.436 and SD= 6.008.

In order to determine whether there was a significant difference between the NNCUQ-pre mean scores of private and public schools, independent samples t-test was used. The significant difference between NNCUQ-post means scores of private and public schools were also compared by independent samples t-test shown in Table 4.6.

Table 4.16. Results of independent samples t-test comparing NNCUQ-pre and NNCUQ-post mean scores of students in the public schools.

School	F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
Private NNCUQ- Pre- Public	1,015	.317	3,902	77	.088	4.900	1.256
			3,859	76.673	.087	4.900	1.270
Private NNAQ- Post- Public	2.320	.132	- 2.122	77	.037	-4.87452	2.29686
			-2.085	66.543	.041	-4.87452	2.33744

As a result of the independent samples t-test analysis, there was no significant difference in the NNCUQ-pre test results for the private (M= 16.16, SD= 6.067) and public (M= 11.26, SD= 5.095), t (77) = 0.436, p= .088. On the other hand, NNCUQ-post mean scores of private and public schools showed significant difference for the private (M= 25.65, SD= 7.436) and public (M= 20.17, SD= 6.008), t (77)= -2.122, p= .037.

The other analysis was done for private school group and public school group separately. Paired samples t-test was used to compare NNCUQ-pre and NNCUQ-post mean scores of private school students. Paired samples t-test conducted for private schools resulted as there was a significant difference in the scores for NNCUQ-pre (M= 40.95, SD= 12.636) and NNCUQ-post tests (M= 81.05, SD= 11.597) of private schools; t (36) = -15.543, p= .000 (See Table 4.7).

Table 4.17. Descriptive statistics comparing NNCUQ-pre and NNCUQ-post scores of students from the private schools.

Private school group	Mean	N	Std. Deviation	Std. Error Mean
NNCUQ-pre	16.16	37	6.067	.997
NNCUQ-post	25.65	37	7.436	1.222

According to Table 4.17, there was a significant difference in the scores of NNCUQ-pre (M=16.16, SD= 6.067) and NNCUQ-post (M=25.65, SD=7.436) for the participants from private schools; t (36) = -8.500, p= .000 (See Table 4.18)

Table 4.18. Results of paired samples t-test comparing NNCUQ-pre and NNCUQ-post scores of students from the private schools.

	Paired Differences					t	df	Sig. (2-tailed)
Private school group	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
NNCUQ-pre NNCUQ-post	-9.486	6.789	1.116	-11.750	-7.223	-8.500	36	.000

These results suggested that NNW had a positive effect on the awareness of nanoscience and nanotechnology for private schools.

Table 4.19. Descriptive statistics comparing NNCUQ-pre and NNCUQ-post scores of students from the public schools.

Public school group	Mean	N	Std. Deviation	Std. Error Mean
NNCUQ-pre	11.26	42	5.095	.786
NNCUQ-post	20.17	42	6.008	.927

According to Table 4.19, there was a significant difference in the scores for NNCUQ-pre (M= 11.26, SD= 5.095) and NNCUQ-post (M= 20.17, SD= 6.008) of public schools; t (41) = -8.134, p= .000.

Table 4.20. Results of paired samples t-test comparing NNCUQ-pre and NNCUQ-post scores of students from the public schools.

	Paired Differences					t	df	Sig. (2-tailed)
Public school group	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
NNCUQ-pre NNCUQ-post	-8.905	7.095	1.095	-11.116	-6.694	-8.134	41	.000

Both descriptive statistics and paired sample t-test concluded that NNCUQ-pre and NNCUQ-post scores of private and public schools differ significantly. These results suggested that NNW had a positive effect on the awareness of nanoscience and nanotechnology for private and public schools.

4.2.3. Comparison of Participants Based on Their Groups

NNCUQ-pre and NNCUQ-post scores of each group were compared with nonparametric sign test and descriptive statistics were obtained for students' pre and post test scores in NNCUQ. Nonparametric test was used to look for a significant difference between NNAQ-pre and NNAQ-post test scores. Nonparametric test was used, since sample size of each group was small. Descriptive statistics and sign test statistics table for each class (See Table 4.21) are given below.

4.2.3.1. Private School 1 (Pr1). 19 students from Pr1 who took NNCUQ-pre attended workshop and they also took NNCUQ-post at the end of the workshop.

Nonparametric sign test was conducted. The difference between pre and post test scores obtained from NNCUQ was analyzed by nonparametric sign test. Exact significance

(2-tailed) value was calculated for each school showed that there was a significant (p=. 000) difference between pre-total and post-total scores of each class.

Table 4.21. Descriptive statistics for the NNCUQ-pre and NNCUQ-post scores of participants from Pr1.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNCUQ-pre	18	17.05	6.859	8	32	.000
NNCUQ-post	18	29.95	6.337	18	38	

As shown in Table 4.21 the mean of scores of the students in the NNCUQ-pre was M=17.05 and the standard deviation of the scores was SD= 6.859. The mean of the scores showed an increase in the NNCUQ-post scores of participants; it was found to be M=29.95 and SD=6.337. Nonparametric sign test was carried out to determine whether the difference between NNCUQ-pre and NNCUQ-post scores was statistically significant or not. It was found that there was a statistically significant difference between NNCUQ-pre and NNCUQ-post scores of participants of Pr1 (p=.000).

4.2.3.2. Private School 2 (Pr2). 19 students from Pr2 who attended workshop took NNCUQ-pre and NNCUQ-post before and after the workshop, respectively.

Exact significance (2-tailed) value was calculated for Pr2 showed that there was a significant (p=.000) difference between NNCUQ-pre and NNCUQ-post scores of Pr2.

Table 4.22. Descriptive statistics for the NNCUQ-pre and NNCUQ-post scores of participants from Pr2.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNCUQ-pre	19	15.22	5.128	5	25	.000
NNCUQ-post	19	21.11	5.666	8	32	

As shown in Table 4.22, the mean of scores of the students in the NNCUQ-pre was M=15.22 and the standard deviation of the scores is SD= 5.128. The mean of the scores showed an increase in the NNCUQ-post scores of participants; it was found to be M=21.11and SD=5.666. It was found that there was a statistically significant difference between NNCUQ-pre and NNCUQ-post scores of participants of Pr2 (p=.000).

4.2.3.3. Public School 1 (Pu1). 17 students from Pu1 who attended workshop took NNCUQ-pre and NNCUQ-post before and after the workshop, respectively.

Exact significance (2-tailed) value was calculated for each school shows that there is a significant (p=. 000) difference between NNCUQ -pre and NNCUQ -post test scores of each school. Descriptive Statistics for the NNCUQ scores of participants from Pu1 Nonparametric test was used to know if there was a significant difference between NNCUQ -pre and NNCUQ -post test scores.

Table 4.23. Descriptive statistics for the NNCUQ -pre and NNCUQ -post scores of participants from Pu1.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNCUQ-Pre	17	8.18	3.414	4	16	.000
NNCUQ-Post	17	19.47	3.793	15	26	

As shown in Table 4.23, the mean of scores of the students in the NNCUQ-pre test was M=8.18 and the standard deviation of the scores was SD= 3.414. The mean of the scores showed an increase in the NNCUQ-post scores of participants; it was found to be M=19.47and SD=3.793.

It was found that there was a statistically significant difference between NNCUQ-pre and NNCUQ-post scores of participants of Pu1.

4.2.3.4. Public School 2 (Pu2). 25 students from Pu2 who attended workshop took NNCUQ-pre and NNCUQ-post before and after the workshop, respectively.

Exact significance (2-tailed) value was calculated for each school shows that there was a significant (p=.000) difference between NNCUQ-pre and NNCUQ-post scores of Pu2.

Table 4.24. Descriptive statistics for the NNCUQ-pre and NNCUQ-post scores of participants from Pu2.

	N	Mean	Std. Deviation	Minimum	Maximum	Exact Sig. (2-tailed)
NNCUQ-Pre	25	13.36	5.024	5	23	.000
NNCUQ-Post	25	20.64	7.176	5	30	

As shown in Table 4.24, the mean of scores of the students in the NNCUQ-pre was M=13.36 and the standard deviation of the scores was SD= 5.024. The mean of the scores showed an increase in the NNCUQ-post scores of participants; it was found to be M=20.64 and SD=7.176.

It was found that there was a statistically significant difference between NNCUQ-pre scores and NNCUQ-post scores of participants of Pu2.

4.3. Statistical Analysis of Research Question 3

- Research Question-3: What are the outcomes obtained from student generated products (open-ended answers and posters) as a result of attending Nanoscience and Nanotechnology Workshop (NNW)?

Nanoscience and Nanotechnology Workshop (NNW) includes various outcomes obtained from students. This section includes the analyses of:

i. An open-ended question (2^{nd} Question) in NNCUQ

ii. Group discussions of benefits and risks of nanoscience and nanotechnology

iii. Nano product design posters

iv. Evaluation of the NNW

v. Pre and Post Interviews

4.3.1. Analysis of an Open-Ended Question (2nd Question) in NNCUQ

The first analysis shown here was about second question of NNCUQ.

The second question was *"Are you familiar with any of nanotechnology applications? If so, give examples of nanotechnology applications. Where did you hear about these applications?"*

For the second question asked in NNCQU, the score of each answer for question 2 obtained from each student were calculated. First, rubric was formed by the researcher. Then, the rubric was checked by the researcher and two undergraduate science students. These students were selected on purpose since they took active roles in development and the implementation of the workshop as group mentors. The rubric of NNCUQ was revised with experts. The percentage of agreement was calculated by evaluating NNCUQ papers 5 of randomly selected students that correspond to 15% of whole number were commonly checked. In other words, 55 questions in total were checked by three experts. 52 questions out of 55 were scored same that gave 95% of agreement.

The students' answers for the second question of NNCUQ were categorized into seven categories. Figure 4.1 and Figure 4.2 show the frequencies and percentages of the NNCUQ -pre and NNCUQ-post test answers. To investigate possible differences among the students' NNCUQ-pre and NNCUQ-post answers for the second question, categories were formed and Chi-Square analysis was conducted. "No answers" were taken as missing data. As the expected value in any category was found to be less than 5, the Chi-Square could not be run for testing with these categories. Then the categories were merged under two categories; "individual benefits" and "global benefits". "Individual benefits" included sub- categories of "nanotechnology products", "textile products" and "hi-tech products". "Global benefits" had sub-categories of "Military/defense", "health" and "ethical/political/socio-economical issues". Answers that fit into more than one category were collected under new categories according to number of response types.

The most frequently answered category in the second question of NNCUQ-pre that was regarding nanotechnology application examples was "no answer"; 60 % of students did not give any nanotechnology application examples. However, "No answer" category took place in NNCUQ-post with 38%. The second most frequent response was "nanotechnology products" with 11.5 % in NNCUQ-pre. This category took the frequency of 10% in NNCUQ-post. The category of "textile products only" took place in NNCUQ-pre and NNCUQ-post; 9% and 41% respectively. This category answer represented the highest frequency for NNCUQ-post. For NNCUQ-pre and NNCUQ-post, the frequencies for the rest of the categories were found respectively as "high-tech products" with 6 % and 1.3%, "more than one category answer" with 4 % and 6 %, "health" with 3 % and 1.3%, "military / defense" with 2 % and 1.3%, "ethical / political / socio-economical issues" with 0% and 10%. The frequencies took place in NNCUQ-pre and NNCUQ-post tests were represented with pie charts shown in Figure 4.1 and Figure 4.2.

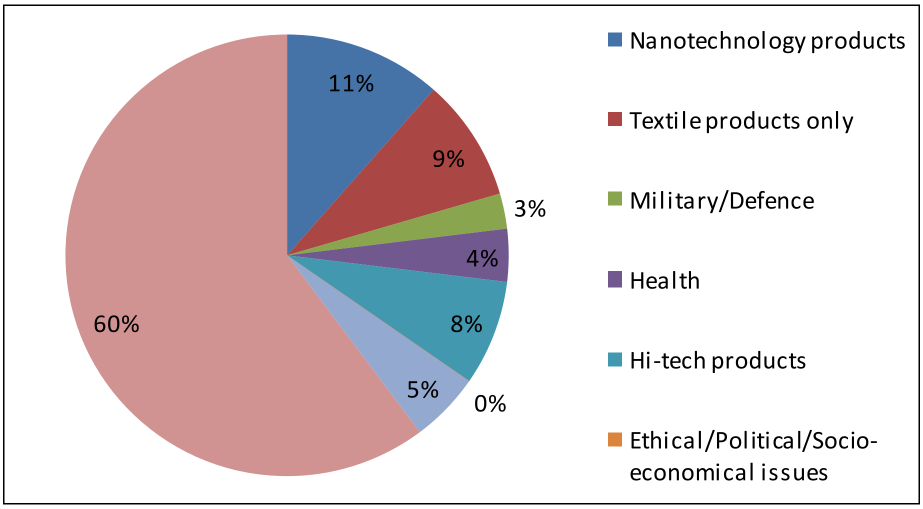


Figure 4.1. Frequency results of initial categories in the second question of NNCUQ-pre.

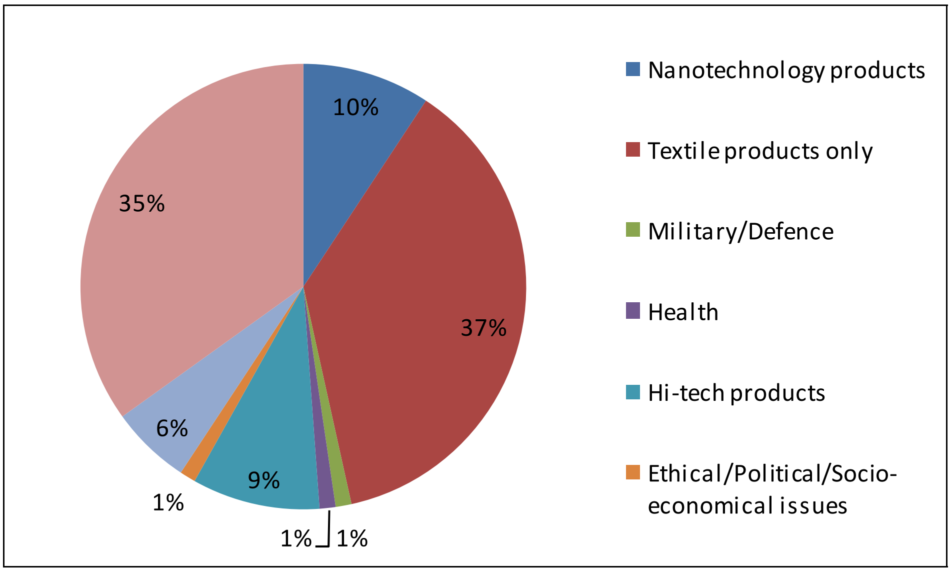


Figure 4.2. Frequency results of initial categories in the second question of NNCUQ-post.

The frequencies of the NNCUQ-pre and NNCUQ-post answers by the new categories were given in Figure 4.3 and Figure 4.4. To investigate possible differences among the students' pre and post test answers by the new categories Chi-Square analysis was run. Since the expected value in any category was found to be less than 5, Chi-Square analysis could not be used. It was revealed that high number of missing data effect on chi-square calculation.

The frequency distribution of the merged categories in the second question of NNCUQ-pre showed that the most frequent answer took place in "no answer" category with 60%. In NNCUQ-post "no answer" category also the most frequent answer with 40%. The second most frequent answer was from the category of "individual benefits" with 32% whereas the "global benefits" category took 8% (See Figure 4.3). In NNCUQ-post, frequency distribution of the categories "individual benefits" and "global benefits" was similar to the NNCUQ-pre frequency distributions. "Individual benefits" took 53% and "global benefits" took 8% (Figure 4.4).

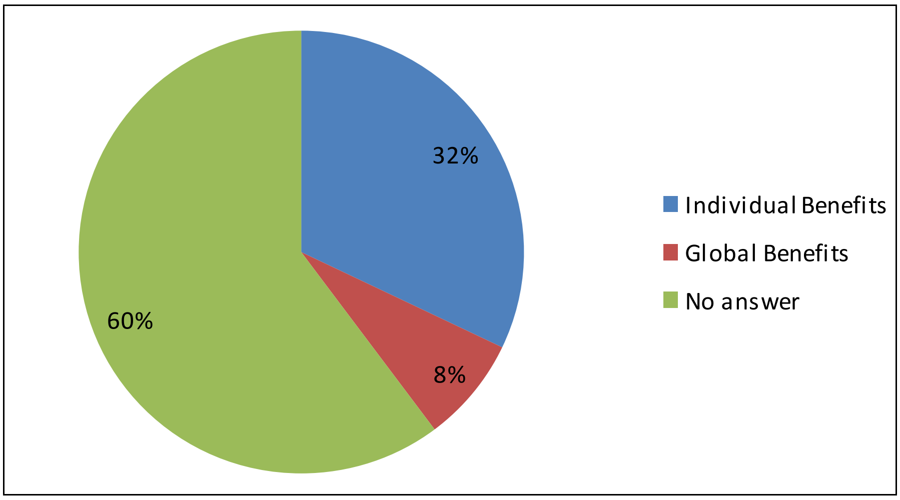


Figure 4.3. Frequency results of merged categories in the second question of NNCUQ-pre.

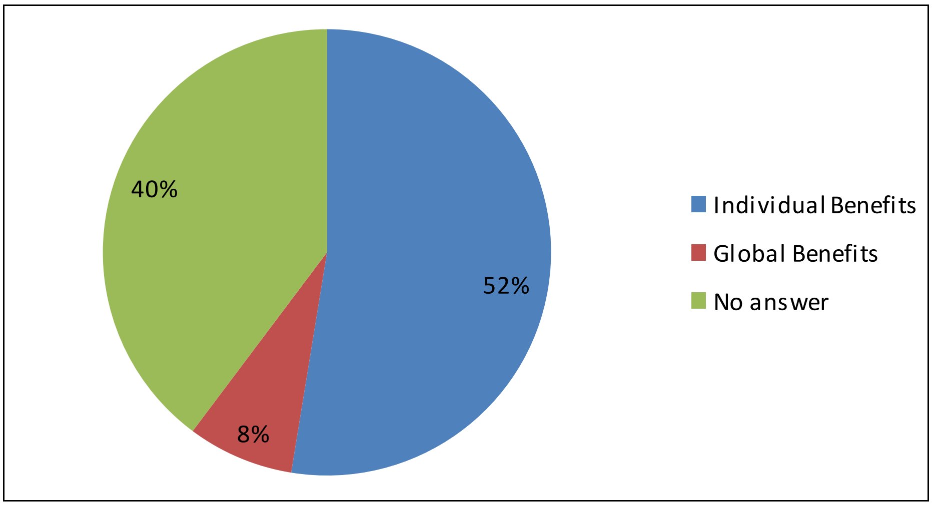


Figure 4.4. Frequency results of merged categories in the second question of NNCUQ-post.

In case of not being able to run Chi-Square analysis, the total number of given answers for NNCUQ-pre and NNCUQ-post were compared without comparing the types of answers. Table 4.25 showed that after attending the workshop the number of responsive students increased. The number of responses given for the second question in NNCUQ-pre was 31. The number of unresponsive students for NNCUQ-pre was 47. In other words, the number of unresponsive students declined.

Table 4.25. Frequency table for response types in NNCUQ-pre and NNCUQ-post.

Response type	Number of responses in NNCUQ-pre	Number of responses in NNCUQ-post	Total number of responses
NNCUQ-pre only	20	20	11
NNCUQ-post only	11	0	27
Both NNCUQ-pre and NNCUQ-post	0	27	20
No answer	0	0	20
TOTAL	31	47	78

The number of responses for the same question in NNCUQ-post was 47 and the number of unresponsive students was 31 (See Table 4.25). Chi-square test was run according to number of responses given in the second question of NNCUQ-pre and NNCUQ-post. Table 4.26 provides the result of the Chi-Square test. The test statistic was found not statistically significant: χ^2 (1. N=78) =0.39. p=.532. Therefore, we could not conclude that there was statistically significant difference in the number of NNCUQ-pre and NNCUQ-post answers for the second question. Although, the number of students' responses increased from 31 to 47, this increase was not found statistically significant.

Table 4.26. Chi-square analysis for number of responses given for the second question in NNCUQ-pre and NNCUQ-post.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.390[a]	1	.532
Likelihood Ratio	.392	1	.531
Linear-by-Linear Association	.385	1	.535
N of Valid Cases	78		

a: 0 cells (0%) have expected count less than 5. The minimum expected count is 12, 32.

4.3.2. Analysis of Group Discussion of Benefits and Risks of Nanoscience and Nanotechnology

The discussion activity was about “Risks and Benefits of Nanotechnology” first planned as Activity 5 in NNW. In the first implementation done with Pr1, an introduction presentation that included some examples of benefits and risks were shared with students to give them some ideas before group discussions. After presentation, each group was asked to discuss the risks and benefits as a group. It was continued with sharing ideas with other groups. In the second implementation with Pr2, the discussion activity was revised and completed in a different way. This time, whole class separated into two big groups. In other words, three groups combined and formed one big group; the rest three groups combined and formed another group. One group was assigned to list risks of nanotechnology; the other group was assigned to list benefits of nanotechnology. When the group works were completed, groups shared their opinions and each group listed benefits and risks of nanotechnology. This discussion part was followed by a short conclusion presentation that summarizes some of risks and benefits of nanotechnology.

To compare the effectiveness of these two different implementation of same discussion activity; the first implementation done with Pr1 was repeated by Pu1, the second implementation done with Pr2 was repeated by Pu2.

4.3.2.1. The discussion activity of Pr1 and Pu1. The benefits and risks of nanotechnology categories given in the discussion presentation were listed as:

i. “Sağlık – Health”

ii. “Çevre - Environment”

iii. “Ucuz ve kaliteli nanoteknoloji ürünleri - Nanotechnology Products”

iv. “Ulusal Güvenlik ve Savunma - Military/ Defense”

v. “Etik, sosyal, ekonomik durum - Ethical/Political/Socio-economical issues”.

For each of these categories mentioned in the discussion presentation, different examples were given from each category. The examples were listed in Table 4.27 . This table would enable to see whether students' answers were the same or similar to the examples mentioned in the discussion presentation or not. In other words, it would reveal that if students would come up with different examples of benefits and risks of nanotechnology or not.

Table 4.27. Examples of benefits and risks of nanotechnology for each initial category in the discussion presentation.

Benefits and Risks of Nanotechnology Categories	The Discussion Presentation Benefits of Nanotechnology Examples
Health	*"Nanoparçacıklar canlı hücrelerin içine girebilir ve organlarda birikebilirler - Nano particles can enter into living cells and can accumulate in organs" – (Environmental Protection Agency, 2003).* *"Proteinlerin nano parçacıklara eklenmesiyle, protein şeklini ve kan pıhtılaşmasına neden olan işlevini değiştirebilir. - With the addition of proteins to nano-particles, protein shape and coagulation function of blood can be changed)"* *"Nano parçacıklar besin zincirine girip; insan sağlında bilinmeyen etkilere yol açabilirler. - Nano particles entering the food chain, may cause unknown effects in human health"* *"Kimyasal ve yapısal özelliklerinin değişmesi, zehirli ve kanserojen etkilerin oluşmasına, hücrelerde uçuculuk, yanabilirlik, süreklik ve yığılmalara neden olabilir. - Changes in the chemical and structural properties might cause to formation of toxic and carcinogenic effects, cell volatility, flammability, continuity, and aggregates"* *"Yüksek miktarda nano- parçacık solunumu akciğerlere zarar verebilir. - Inhalation of high amounts of nano-particles may cause lung damage" (National Aeronautics and Space Administration, NASA, 2002).* "*Bucky ball balıklarda büyük beyin hasarlarına yol açabilmektedir. – A Bucky ball can lead to brain damage in big fish" (American Chemical Society, 2004).*
Environment	*"Bakterilerle ayrışmayan çevre kirliliğine neden olan nano parçacıklar bulunmakta. - There are nano-particles that do not decompose by bacteria and cause environmental pollution"* "*Güneş kremlerinde bulunan titanyum dioksit nano parçacığının atık sularla beraber denizlere, göllere ve nehirlere akması. - Flow of nano-particle, titanium dioxide in sunscreen with waste waters to seas, lakes and rivers"* "*Titanyum dioksit nano parçacıklarının fare beynindeki sinir hücrelerinde hücre ölümlerini tetiklemesi. - Titanium dioxide nano-particles in mouse brain nerve cells, triggering cell death"*

Table 4.27. Examples of benefits and risks of nanotechnology for each initial category in the discussion presentation cont.

Benefits and Risks of Nanotechnology Categories	*The Discussion Presentation* *Benefits of Nanotechnology Examples*
Nanotechnology Products	*"Tekstil. – Textile"* *"Kıyafet,tshirt, spor ürünleri,mama önlüğü,çorap,havlu,araba koltuk,uyku seti,banyo ürünleri. - Clothing, T-shirt, sporting goods, bib, socks, towels, car seat, sleeping set, bathroom products"* *"Plastik. - Plastics"* *"Oyuncak, bebek ürünleri, ev ürünleri, mouse klavye, pet şişe, telefon. - toys, baby products, household products, mouse, keyboard, plastic bottles, telephone"* *"Tıp. – Medicine"* *"Maske, eldiven, bandaj, kozmetik, deodorant, ilaç, sterilize etmek. - Mask, gloves, bandages, cosmetics, deodorants, medicines, sterilizing"* *"Beyaz Eşya. - White goods"* *"Masa, sandalye, banyo, duş, mutfak eşyası, buz dolabı, çamaşır makinesi. - Tables, chairs, bathroom, shower, kitchen utensils, refrigerator, washing machine"*
Military/ Defense	*"Yüksek miktarda akıllı silahlar - High amount of smart weapons"* *"Minyatürleştirilmiş, robot silahlar ve güvenilir uzaktan kapama olmadan yapılan akıllı hedef- aramaya yönelik askeri mühimma. - Miniaturized robotic weapons, and smart ammunition for target searching without reliable remote off"*
Ethical/ Political/ Socio-economical issues	*"Zengin ve fakir ya da gelişmiş ve gelişmekte olan ülkeler arasında uçurum. - The gap between developed and developing countries or rich and poor"* *"Nano üretim tekniklerinden kaynaklanan milyonlarca işten çıkarılma. - Dismissal of millions due to Nano-manufacturing techniques"*

After presenting the examples of benefits and risks shown in Table 4.27, students were asked to make small group discussions about these examples. The mentors of each group led the discussions.Then, each group presented their ideas to the entire group.

4.3.2.2. <u>The discussion activity of Pr2 and Pu2.</u> The answer categories obtained from group responses of Pr2 and Pu2 schools are shown in Figure 4.5 and Figure 4.6. This figure shows the frequencies of examples coming from all groups regardless of benefits and risks. Since only the Pr2 and Pu2 schools were asked to list the benefits and risks on a poster, the frequency table includes the answers obtained from these two groups.

The frequency distribution obtained from the initial categories in the group discussion on benefits and risks of nanotechnology showed that 47% of the respondents from Pr2 and 35.6 % respondents from Pu2 gave responses from the category of "ethical/political/socio-economical issues". The second most frequent answer category was "health"; 30% of students from Pr2 and 22% of students from Pu2 gave similar answers. "Military / defense" category took 20% for Pr2 and 11% for Pu2. From Pr2, no answers were obtained from the category of "nanotechnology products" and "hi-tech products", whereas the frequencies from these two categories for Pu2 were 20% and 9% respectively. The frequency distributions of initial categories obtained from the group discussion of Pr2 and Pu2 on benefits and risks of nanotechnology were shown in Figure 4.5 and Figure 4.6 in that order.

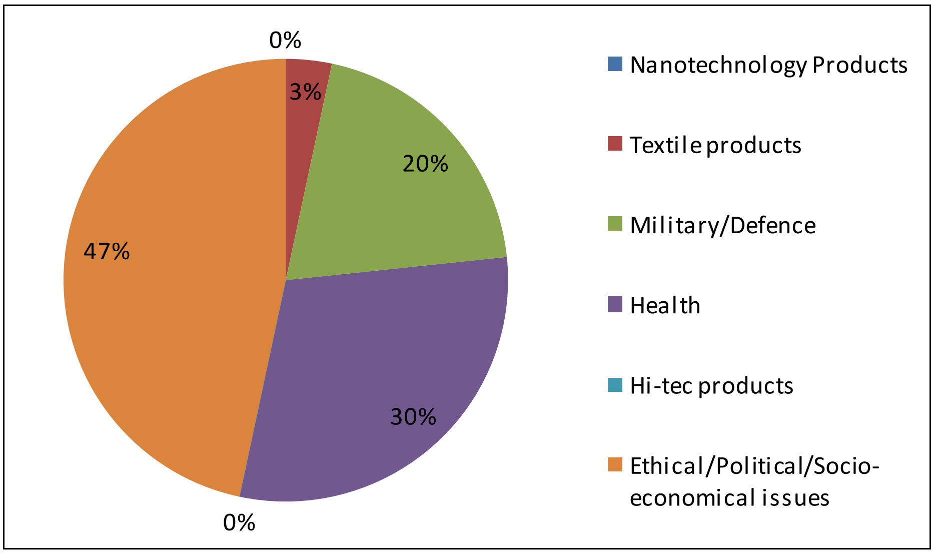


Figure 4.5. Frequency results of initial categories in the group discussion of Pr2 on benefits and risks of nanotechnology.

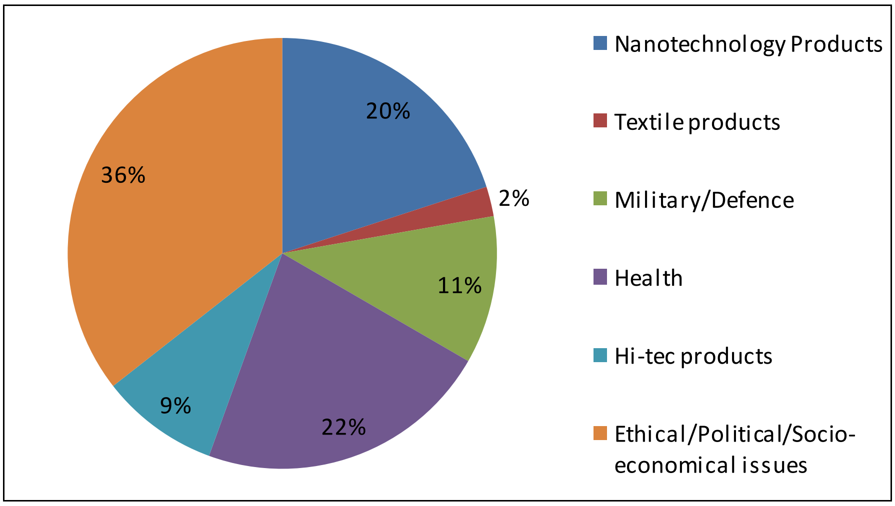


Figure 4.6. Frequency results of initial categories in group discussion of Pu2 on benefits and risks of nanotechnology.

The initial categories were merged into "individual" and "global" categories. The frequencies were calculated according to these categories. It was shown in Figure 4.7 and Figure 4.8 that both Pr2 and Pu2 students' answer frequencies higher in the category of "global". The frequency percentages were 97% for Pr2 and 69% for Pu2. The frequencies for the category of "individual" were 3% and 31%. The highest frequency answer category, which was "individual", could easily be obtained from these figures.

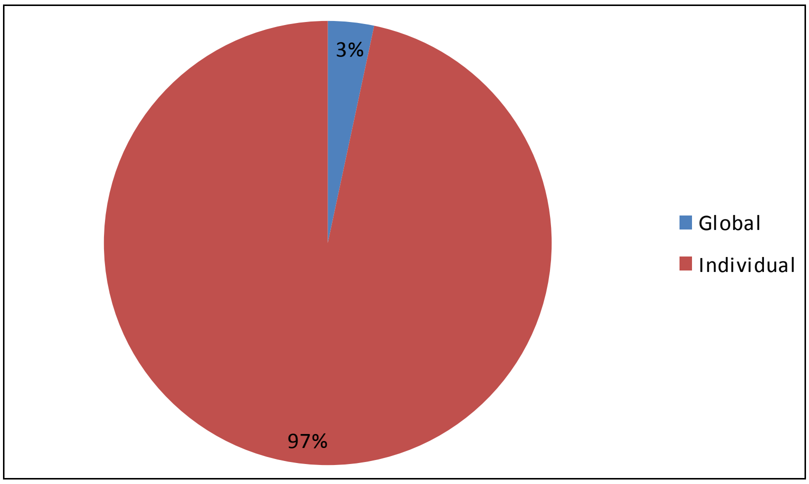


Figure 4.7. Frequency results of merged categories in the group discussion of Pr2 on benefits and risks of nanotechnology.

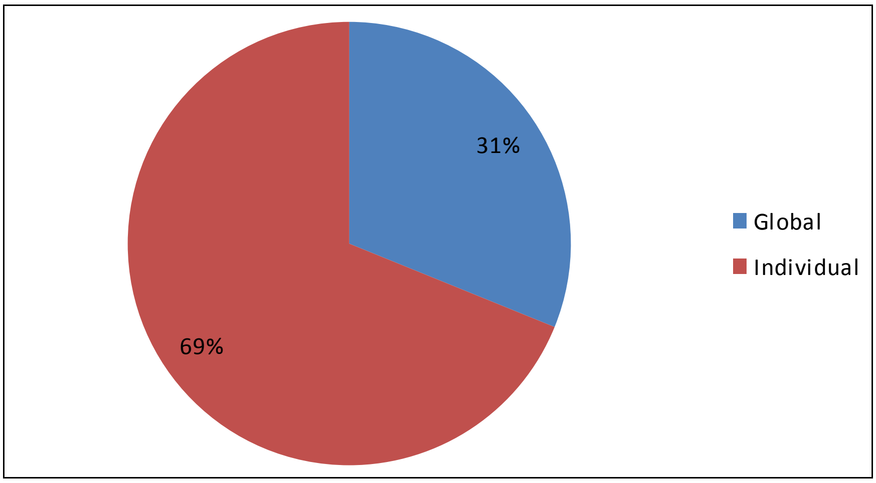


Figure 4.8. Frequency results of merged categories in the group discussion of Pu2 on benefits and risks of nanotechnology.

Among the all the given examples obtained from the group discussions of Pr2 and Pu2; the examples given for only benefits and the examples given for only risks were analyzed separately. This analysis was done in order to compare the frequencies of nanotechnology benefits examples and nanotechnology risks examples. The frequencies for benefits of nanotechnology examples were given in Figure 4.9 and Figure 4.10.

The frequencies of the category answers showed that the category of "health" was declared as the category with highest frequency for Pr2. In Pu2, the highest frequency belonged to the category of "nanotechnology products" with 31%. Then, the category of "ethical/political/socio-economical issues" was found as the second highest frequency category for both Pr2 and Pu2 with frequencies of 36% and 21% respectively. 14% of students from Pr2 gave responds from the category of "military /defense" and only 7% of students gave responds from the category of "textile products". No responses were taken from the answer categories of "nanotechnology products" and "hi-tech products" in Pr2. In Pu2, the "textile products" category was declared with 14%; "hi-tech products" with 10%. The frequency of the "military /defense" category took 8%.

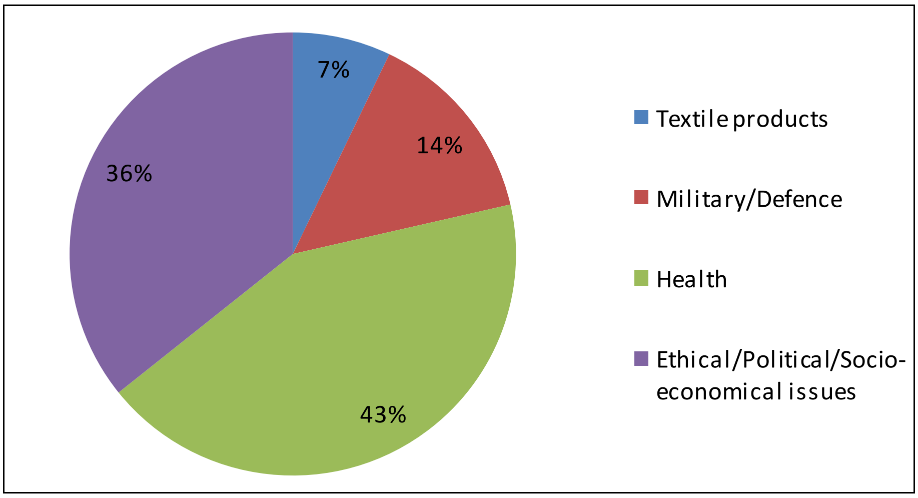


Figure 4.9. Frequency results of initial categories in the group discussion of Pr2 on benefits of nanotechnology.

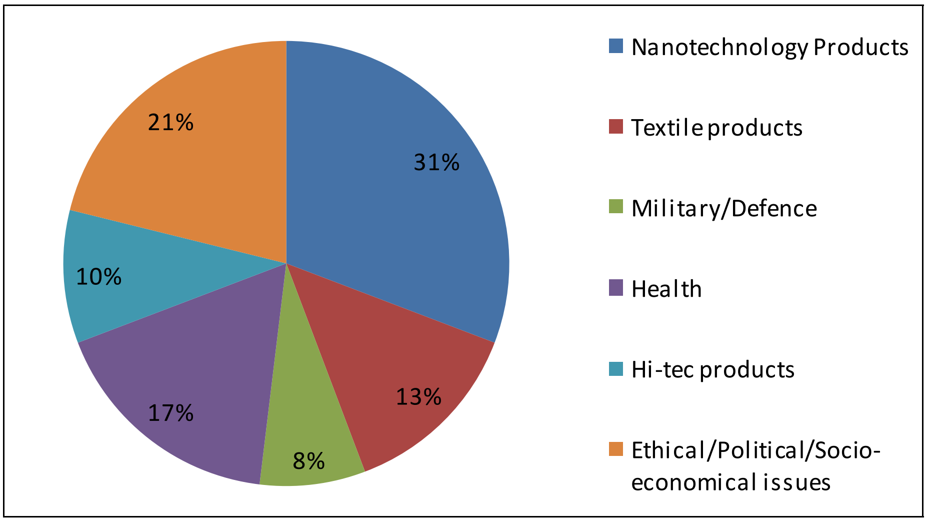


Figure 4.10. Frequency results of initial categories in the group discussion of Pu2 on benefits of nanotechnology.

For each school; Pr2 and Pu2 the merged category example frequencies coming from the discussion of benefits were represented in Figure 4.11 and Figure 4.12.

In Pr2, the highest frequency category was “global” with 93%, the category of “individual” was declared with 7% in the second order (See Figure 4.11). In Pu2, the highest frequency belonged to the category of “individual” with 54%, the “global” category was with 46% (See Figure 4.12).

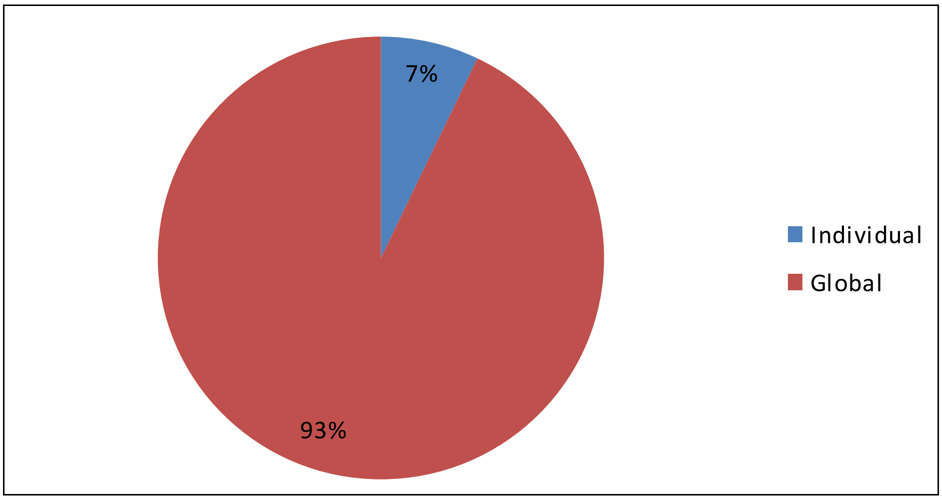


Figure 4.11. Frequency results of merged categories in the group discussion of Pr2 on benefits.

In Pr2 examples of global benefits are given more compared to individual benefits.

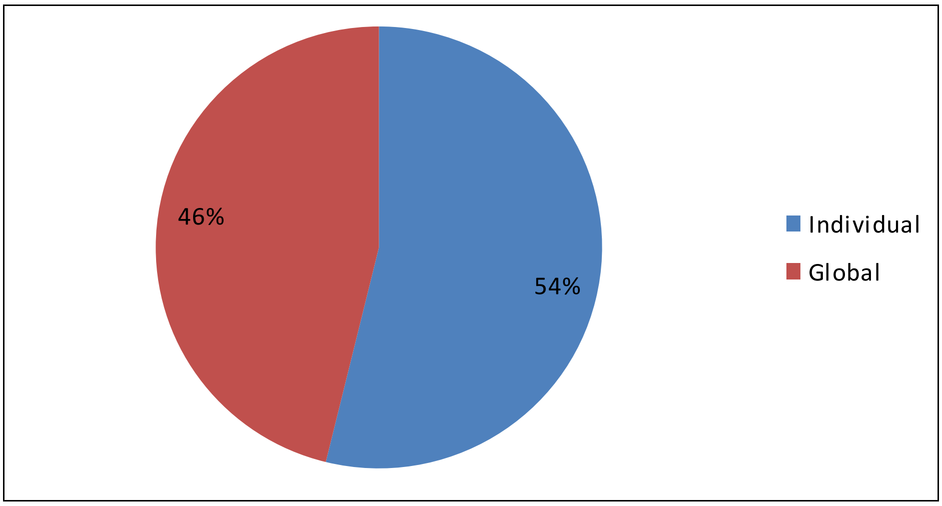


Figure 4.12. Frequency results of merged categories in the group discussion of Pu2 on benefits.

Each answer category included various benefits of nanotechnology examples obtained from Pr2 and Pu2 students were represented in Table 4.28.

Table 4.28. Specific benefit examples given for each initial category in the group discussion of Pr2 and Pu2.

Initial Categories	Pr2 Benefits of Nanotechnology Examples	Pu2 Benefits of Nanotechnology Examples
Nanotechnology Products	-	*"Fön daha kalıcı olur – Straighting the hair will be more permanent"* *"Temizlik kolaylaşır – Cleaning will be easier"* *"Gıda ürünlerinin bozulmasını geciktirir - Retard the deterioration of food products"* *"Kozmetik sektöründe daha etkili ürünler yapılabilir - Cosmetics can be made more effective products industry"* *"Bitkinin ölmesini geciktirir - Delays the death of the plant"* *"Birçok tekstil ürünlerinin temizliğini sağlar - Ensures cleanliness of many textile products"* *"Arabaların çizilmesini engeller - Prevents scratching cars"* *"Boyalarda kullanılır -Used in paints"* *"Uzun raf ömrü - Long shelf life"* *Bozulmayan makyaj (non-perishable make-up)* *Gıdaların raf ömrünü uzatır - Extends the shelf life of foods"* *"Daha sağlam ürünler üretilir - More robust products"* *"Tadı bitmeyen sakız - Chewing gum with non-ending taste"* *"Evlerin dış cephelerinde kullanılarak kendi kendini temizlemesini sağlar - Provides a self-clean exteriors of homes"* *"Bayanlar saçlarına nanoteknoloji uygulanırsa saçlarını hergün yıkamak zorunda kalmaz.- Women do not have to "wash hair every day if nanotechnology is applied"* *"Su geçirmeyen ayakkabılar - Waterproof footwear"*

Table 4.28. Specific benefit examples given for each initial category in the group discussion of Pr2 and Pu2 cont.

Initial Categories	*Pr2 Benefits of Nanotechnology Examples*	*Pu2 Benefits of Nanotechnology Examples*
Textile products	*Su geçirmez - water proof*	*"Yanmayan kıyafetler yapılır - Production non-flammable clothing"* *"Kir, su tutmayan kullanışlı kıyafetler yapılır -Production dirt, water-repellent useful clothing"* *"Üşütmeyen kıyafetler yapılır - Production of non-chill clothes"* *"Giyim sektöründe büyük gelişim: su geçirmeyen mayo. leke tutmayan gece elbiseleri ve birçok dayanıklı kıyafet. - A significant development in the garment industry: water resistant swimwear, dirt- repellent evening dresses, and many resistant clothing"* *"Şemsiyelerde yağmurluklarda kullanılabilir - Can be used in umbrellas and raincoats"*
Military/Defense	*Görünmez tank - invisible tank* *Savunma - defense*	*"Savunmada kullanılır - Used for defense"* *"Ülke savunmalarında işe yarar - Helps defense of the country"* *"Askeri alanda çok büyük gelişim gösterir - Shows a tremendous development in the military field"* *"Askeri alanda kıyafetlerde kullanımı yaygınlaşabilir - The use of clothing might become widespread in the military field"*
Health	*Kanser tedavisi - treatment of cancer* *Yapay bağışıklık - artificial immunity* *Yapay organ - artificial organ* *Robotlarla tedavi - treatment with robots* *Uzun ömür - long life* *Sağlık - health*	*"Mikroplardan korur - Protects from germs"* *"Tıpta çağ açabilir belki de kansere çözüm bulunabilir - A new era in medicine. Maybe cancer will be cured* *"Yaşlanmayı engeller - Prevents aging"* *"Kırışıklıklar azalır - Decreases wrinkles"* *"Antibakteriyel koruma sağlar - Provides antibacterial protection"* *"İnsanların yaşlanmasını geciktirir - Delays aging in humans"* *"Tedavi süresince tüm vücud yerine sadece hasta olan organa tedavi uygulanması - Treatment of the ill organ only instead of whole body"* *"Nanorobotlar üretilip hastalığa yönelik bir tedavi uygulanabilir - Nanorobots can be produced to treat a medication for the disease"* *"İlaçlarda kullanılabilir - Might be used in medicines"*

Table 4.28. Specific benefit examples given for each initial category in the group discussion of Pr2 and Pu2 cont.

Initial Categories	*Pr2 Benefits of Nanotechnology Examples*	*Pu2 Benefits of Nanotechnology Examples*
Hi-tech Products	-	*"Moleküler bilgisayarlar ortaya çıkar - Molecular computers will be used"* *"Küçük boyutlardaki belleklerde çok fazla datamız saklarız - Small-sized memory to store too much data"* *"Bazı frekanslarda görünmez olma olayı güzel -It is good to be invisible at some frequencies"* *"Zamandan kazanır işlerimizi daha kolay yaparız - Saves time, makes it easier to make work done"* *"Daha küçük maddeler hakkında bilgi edinmemizi sağlar - Helps us learn more about small sized particles"*
Ethical/Political/Socio-economical issues	*Alandan kazanç/ağırlıktan kazanç - Space gain / weight gain* *Zamandan kazanç - Save time* *İnsan hatası azalır - Human error is reduced* *Tarihi eserlerin korunumu -* *Conservation of historical monuments* *Sokak temizliği - Street cleaning*	*"İnsanlar sosyalleşir - Helps people to get socialize"* *"Turizm gelişir - Develop turism"* *"Yoldan enerjiden tasarruf - Energy saver"* *"Havayı temizler - Cleans air"* *"Yeni meslekler ortaya çıkar - New professions arise"* *"Daha küçük aletler üretilebildiği için taşınması kolay olur - Small instruments that are produced will easily be handled"* *"Günlük hayatta kolaylık sağlar - Provides convenience in daily life"* *"Zamandan tasarruf edilir - Saves time"* *"Geri dönüşüm bakımından çevre kirliliği azalır.- Reduces environmental pollution in terms of recycling"*

Two of the initial categories, which were obtained in the group discussion of Pr2 and Pu2 on benefits of nanotechnology, did not take place in the discussion of risks of nanotechnology. These categories were; "nanotechnology products", "textile products".

The frequency distribution showed that most of the Pr2 and Pu2 students gave answers from the category of "ethical / political / socio-economical issues"; Pr2 with 50% and Pu2 with 52%. The second most frequent answer category for Pr2 was "military

/defense" with 29%; for Pu2 was "health" with 29%. The category of "health" came third in the frequency order for Pr1 with 21%. None of the students from Pr2 gave answers from the category of "hi-tech products". In Pu2, "military and defense" category was declared with 14%, which was followed by the category of "hi-tech products" with 5%.

The frequency distributions could also be seen from the pie charts represented in Figure 4.13 and Figure 4.14.

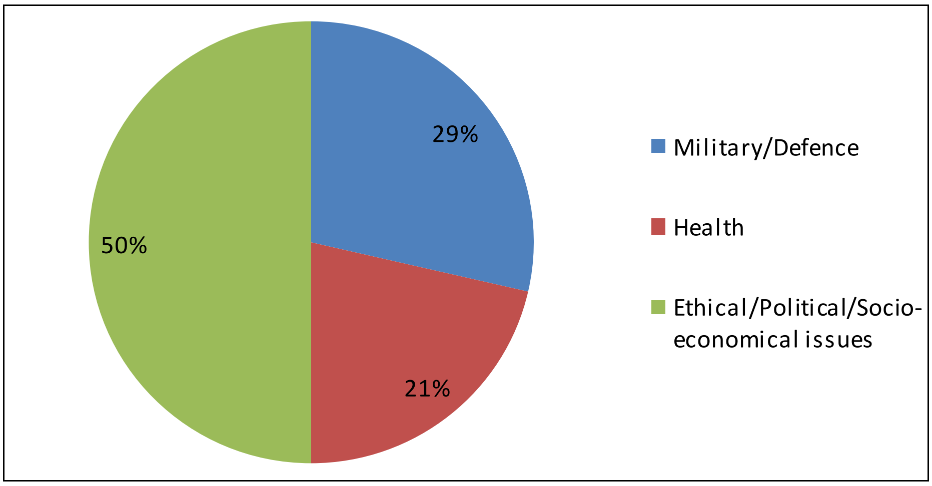


Figure 4.13. Frequency results of initial categories in the group discussion of Pr2 on risks.

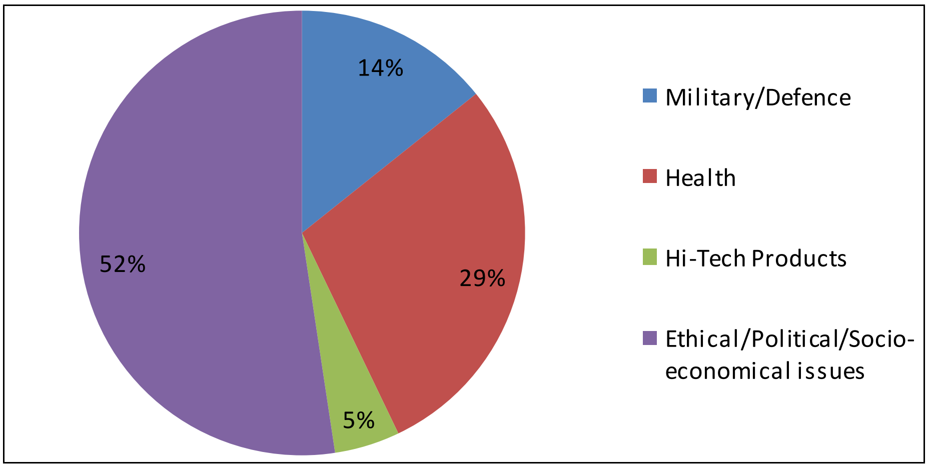


Figure 4.14. Frequency results of initial categories in the group discussion of Pu2 on risks.

For each school Pr2 and Pu1 the new category example frequencies coming from three groups that discuss risks were calculated Textile products were merged into individual risks category; military / defense, health and ethical / social /political / socio-economical issues merged into global risks category. In Pr2, all the specific examples given for the risks of nanotechnology were represented from the "global" category with 100%. No examples of risks from "individual" category were stated. For Pu2 only 5% of risk examples came from "individual" category. The category of "global" took 95% (see Figure 4.15)

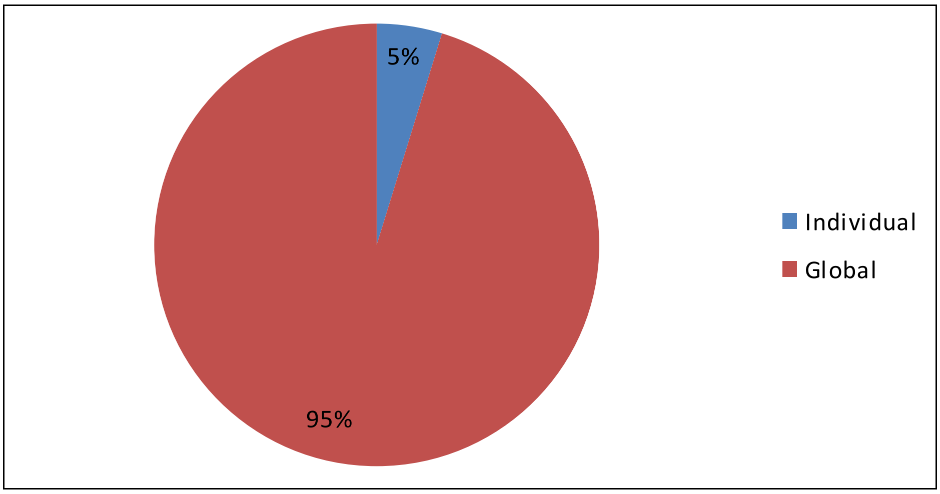


Figure 4.15. Frequency results of merged categories in the group discussion of Pu2 on risks.

Each answer category included various risks of nanotechnology examples obtained from Pr2 and Pu2 students were represented in Table 4.29.

Table 4.29. Risk examples in each category in group discussion Pr2 and Pu2.

Categories	Pr2 Risks of Nanotechnology Examples	Pu2 Risks of Nanotechnology Examples
Military/Defense	*"Silahlanma. – Arms"* *"Askeri ekipman. - Military equipments"* *"Savaş. - War"* *"Radyasyon. - Radiation"*	"*Soğuk savaş.* - Cold *war"* "*Savaşlara neden olabilir.* - Cause *wars"* "*Silahlar ve yol açtığı iç ve dış savaşlar. - Weapons and cause of internal and external wars*" "*Yeni geliştirilecek kimyasal,biyolojik silahlar daha çok insanın ölmesine sebep olur.- Invention of new chemical and biological weapons will cause more people to die"*
Health	*"Alerjik. –Allergic"* *"Sağlık sorunları. - Health problems"* *"Kanserojen. - Carcinogenic"*	*"Fazla nano cilde zarar. - Much amount of nano particles are harmful for body"* *"Vücudumuza nano girmesin. -Nano particles should not diffuse to our body"* *"Sağlık problemlerini beraberinde getirir. - Brings health problems"* *"İnsan vücudunun hava almaması. - Blocks pores of skin"* *"Cilde zarar verir. - Harmful for skin"* *"Nano parçacıklar çok küçük olduğu için vücudumuza çok kolaylıkla girebilir. - Nano-particles are very small, very easily diffuse to the body"* *"Cildi bozar. - Damages skin"*
Hi-Tech Products	-	*"Radyasyon ve teknolojiyle sorunlar. - Problems relate to radiation and technology"*

Table 4.29. Risk examples in each category in group discussion Pr2 and Pu2 cont.

Categories	Pr2 Risks of Nanotechnology Examples	Pu2 Risks of Nanotechnology Examples
Ethical/Political/ Socio-economical issues	*"Hizmet Sektörü. - Service Sector"* *"Sanayi. – Industry"* *"Spidermanler artacak. - Increase number of spidermen"* *"Tembellik. – Laziness"* *"İşsizlik. – Unemployment"* *"Üretimin Düşmesi. - Decline in production"*	*"Özel hayata müdahale - Interference with private life"* *"İşsizlik oranı artar. - Unemployment rate will increase"* *"İnsanlar aylak aylak dolaşır. – Laziness"* *"Hırsızlık artar. - The increase in number of theft"* *"Ekonomik sorunlar. - Economic issues"* *"Çevre kirliliği. - Environmental pollution"* *"Özel hayatı riske atıyor. - Private life in risk"* *"Hava kirliliği. - Air pollution"* *"Gecko örümceğinden yola çıkarak hırsızlık olabilir. - Gecko inspires theft"* *"Devletler arası ilişkilere zarar verebilir ve hiç beklenmedik anda savaşlar açılabilir. - Damage the relations between the state and unexpected wars"* *"Özel hayata tecavüze hayır. – No to interfering private life"* *"Devletler bunu kötüye kullanıp sivil insanların ölmesine sebep olabilir. - Misuse of nanotechnology by the states may cause the deaths of many civilian people"* *"İnsanlar eşlerini aldatamaz, görünmezlik pelerini yüzünden.- With the invisibility cloak, people can easily deceive their mates"* *"Özel hayat denen bir şey kalmaz. İnsanlar boşanır. No more private lives, people get divorce"*

Figure 4.16. Example of a group discussion poster from Pr2 about risks of nanotechnology.

As it was mentioned before, the discussion activity was done in two different ways. First implementation was with Pr1 and Pu1 students, the second implementation was done with Pr2 and Pu2 students. In Pr1 and Pu1, all students discussed both risks and benefits of nanotechnology after listening to a presentation. In Pr2 and Pu2, three groups discussed benefits and the other three groups discussed risks. The aim of implementing two different ways of discussion was to facilitate the NNW with an effective discussions activity. In order to decide which implementation would be more effective, the NNAQ-post results of Pr1 and Pu1 were compared with the NNAQ-post results of Pr2 and Pu2. Pr1 and Pu1were taken as one group and labeled as Group1; Pr2 and Pu2 were also taken as one group and labeled as Group2.

The independent samples t-test was conducted to compare the NNAQ-post results of Group1 (Pr1 and Pu1) and Group2 (Pr2 and Pu2). There was a significant difference in the scores for Group1 (Pr1 and Pu1) and for Group2 (Pr2 and Pu2); $t\ (76) = 2.7$, $p = 0.008$. When the groups discussed both risks and benefits they scored higher in NNAQ, then the groups discussed one or the other (See Table 4.30).

Table 4.30. Descriptive statistics comparing NNAQ-post test scores of group1 (Pr1 and Pu1) and group2 (Pr2 and Pu2).

	Groups	N	Mean	Std. Deviation	Std. Error Mean
NNAQ-post scores	1	35	87.20	9.689	1.638
	2	43	81.00	10.247	1.563

Table 4.31. Independent samples t-test to compare NNAQ-post mean scores of group1 (Pr1 and Pu1) and group2 (Pr2 and Pu2).

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
NNAQ-post scores	2,723	76	.008	6.200	2.277

The comparison of NNAQ-post results of Group1 (Pr1 and Pu1) and Group2 (Pr2 and Pu2) was followed by another independent samples t-test. It was conducted to compare responses given in the second question of NNCUQ. The results of this question were analyzed since the question was about "benefits and risks of nanotechnology". The question was *"Are you familiar with any of nanotechnology applications? If so, give examples of nanotechnology applications. Where did you hear about these applications?"*

The independent samples t-test was conducted to compare the NNCUQ-post results of Group1 (Pr1 and Pu1) and Group2 (Pr2 and Pu2). There was a significant difference in the scores for Group1 (Pr1 and Pu1) and for Group2 (Pr2 and Pu2); t (77) =2.4, p=0.17. This result showed that the group who discussed both risks and benefits outperformed the ones who did only one of them (See Table 4.32).

Table 4.32. Descriptive statistics comparing NNCUQ-post (2^{nd} question) test scores of group1 (Pr1 and Pu1) and group2 (Pr2 and Pu2).

	Schools	N	Mean	Std. Deviation	Std. Error Mean
posttest	1	35	.74	.443	.075
	2	44	.48	.505	.076

Table 4.33. Independent samples t-test to compare NNCUQ-post (2^{nd} question) mean scores of group1 (Pr1 and Pu1) and group2 (Pr2 and Pu2).

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Mean
NNAQ-pre and NNAQ-post scores	2.448	77	.017	.266	.108

As shown in Table 4.31 and Table 4.33, the independent samples t-tests which were conducted to compare NNAQ-post results and the NNCUQ-post results revealed that implementing discussion activity in two different ways had an effect on awareness.

4.3.3. Analysis of Designing a Nano Product Poster Activity:

As it clarified in the previous sessions, the last activity that students took a part was “design of a nanotechnology product”. Each group of students was asked to come up with a new nano product idea, with a slogan and an explanation of it. Each group created a poster that represents their product design idea.

Each poster was analyzed and the product ideas were placed in the categories that were used in the second question of NNCQ and group discussion results. The frequency distributions of the design ideas were shown in Figure 4.17 to Figure 4.22.

The categories that most of design ideas for all groups took in a place were “nanotechnology products”, “health”. The category of “textile products” only observed in Pr1 and Pu2. “Military and defense” observed in all groups except Pr2. “Hi-tech product” category observed in Pr2, Pu1 and Pu2. No products took place in the category of “ethical / political / socio-economical issues”.

Majority of students; 34% from Pr1, 36% from Pr2, 43% from Pu1 and 30% from Pu2 showed that they would like to design a “nano product” related to the “health” category. The second most frequent design category was declared as “nanotechnology products” for Pr1 with 32%; for Pr2 with 34% and for Pu1 with 29%. In Pu2, three of the categories “nanotechnology products”, “textile products” and “hi-tech products” took the same frequency of 20%. The third most frequent design category was found as textile products” for Pr1 with 17%; for Pr2 it was “hi-tech products” with 18%. However, in Pu1 “textile products” and “hi-tech products” categories resulted with same frequency that was 14%. “Military /defense” and “hi-tech products” category took 8% in Pr1. No products were designed relate to the category of “ethical / political / socio-economical issues” in Pr1 and in Pr2. In Pr2, none of the product design ideas were belonged to “military / defense” and “textile products” categories. In Pu1, students did not design any nano products relate to the categories of “military / defense” and “ethical / political / socio-economical issues”. In Pu2, only “ethical / political / socio-economical issues” category did not take place among students’ design ideas.

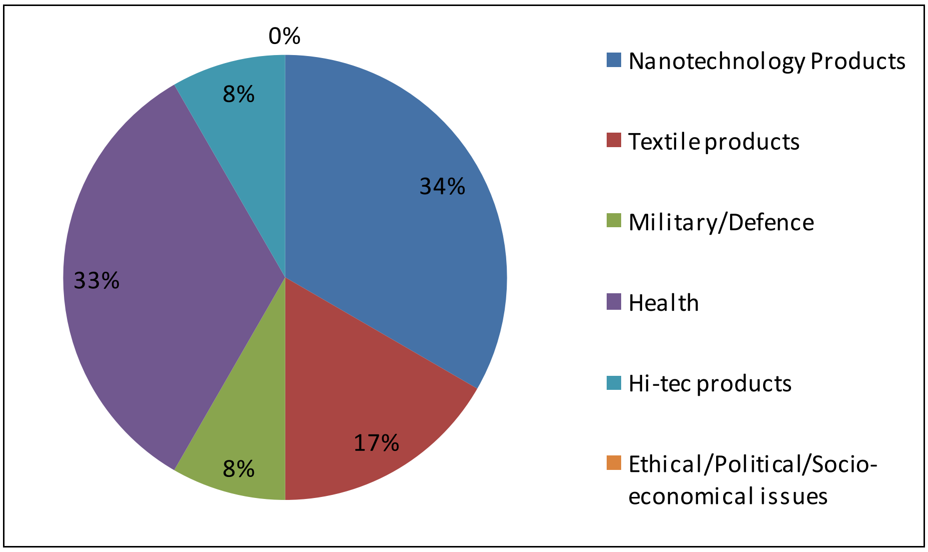


Figure 4.17. Frequency results of initial categories in the poster design activity of Pr1.

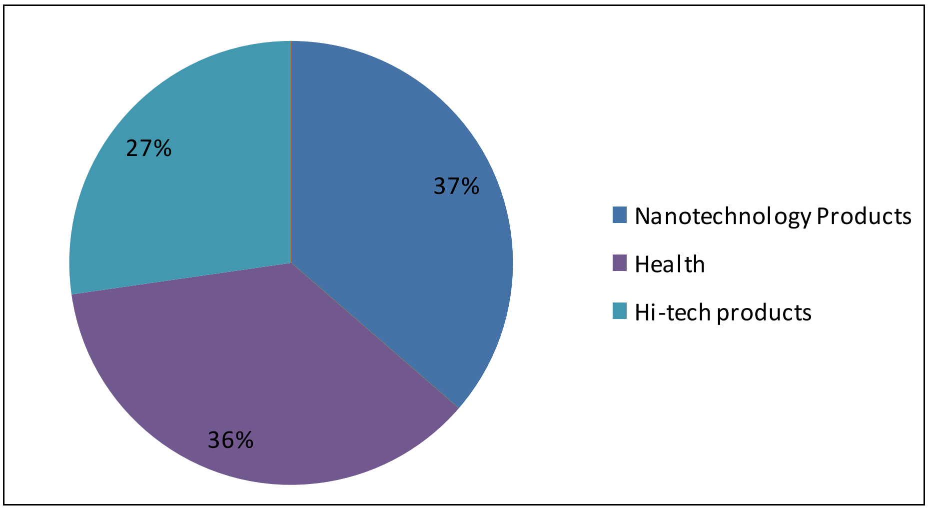


Figure 4.18. Frequency results of initial categories in the poster design activity of Pr2.

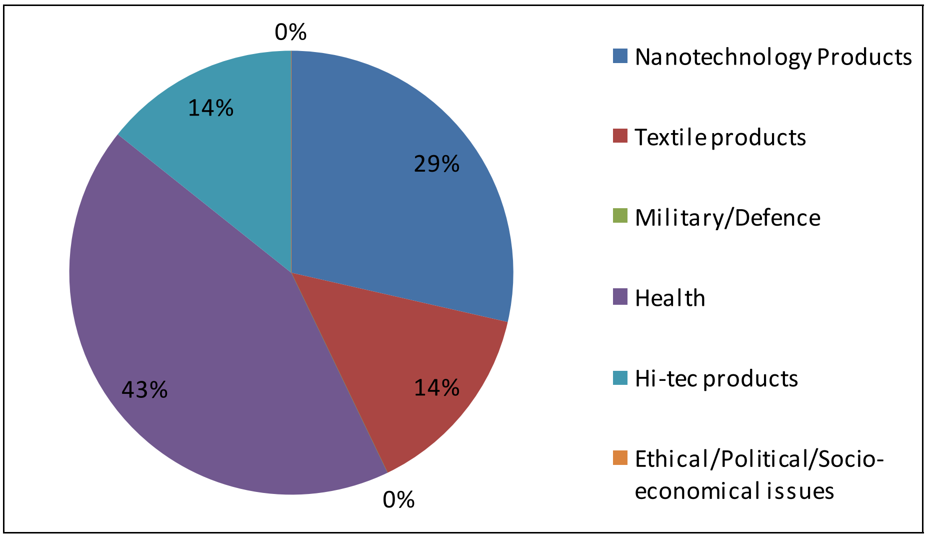


Figure 4.19. Frequency results of initial categories in the poster design activity of Pu1.

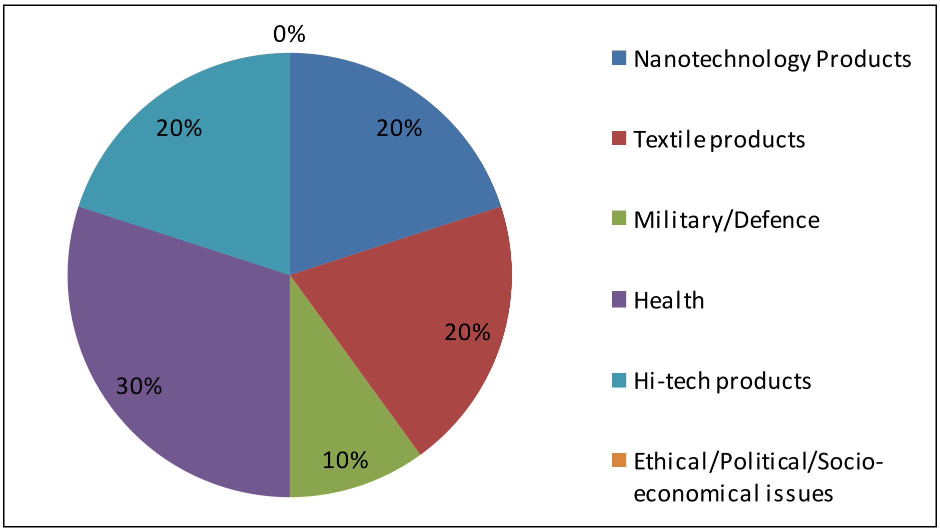


Figure 4.20. Frequency results of initial categories in the poster design activity of Pu2.

The initial categories merged into two categories which were “individual” and “global” as it was done in the second question of NNCQ and group discussion activity.

Figures from Figure 4.21 to Figure 4.24 represented that “individual” category was the most frequent category for Pr1 with 58%; Pr2 with 55% and Pu2 with 60%. For Pu1, the category of “global” had the highest frequency with 57%.

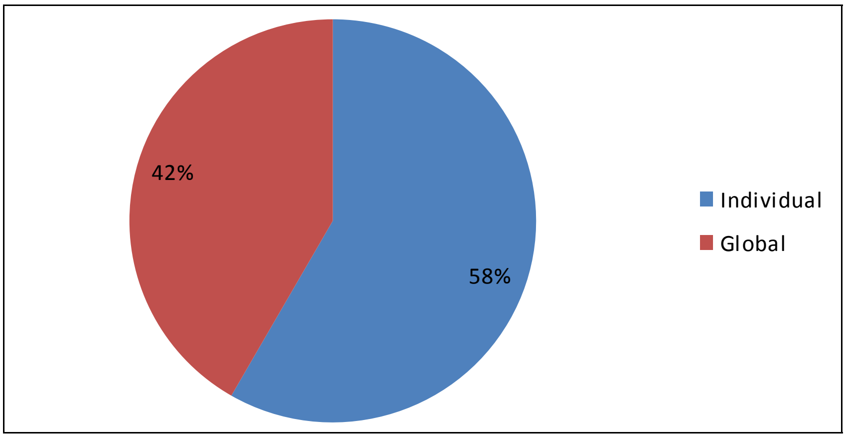


Figure 4.21. Frequency results of merged categories in the poster design activity of Pr1.

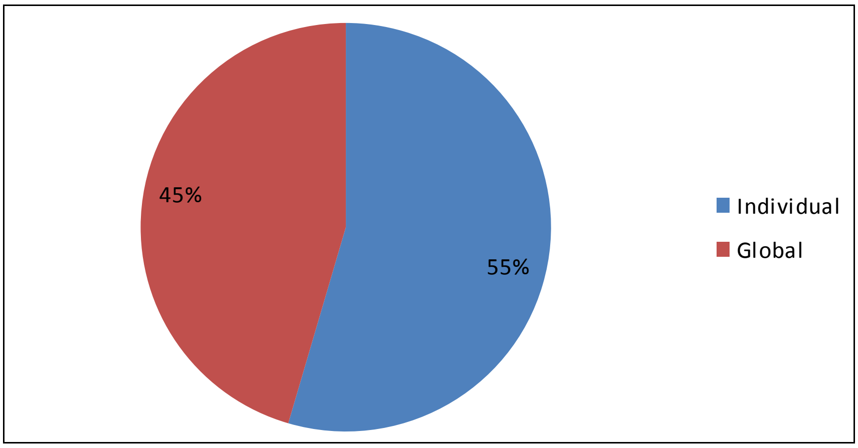


Figure 4.22. Frequency results of merged categories in the poster design activity of Pr2.

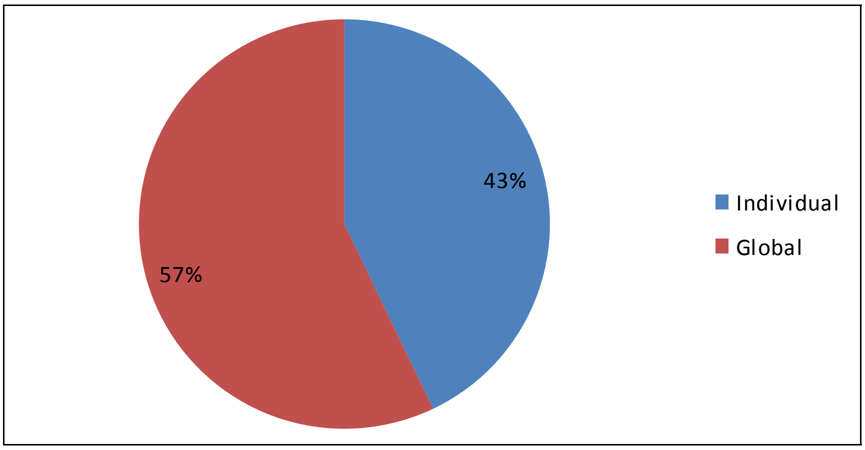


Figure 4.23. Frequency results of merged categories in the poster design activity of Pu1.

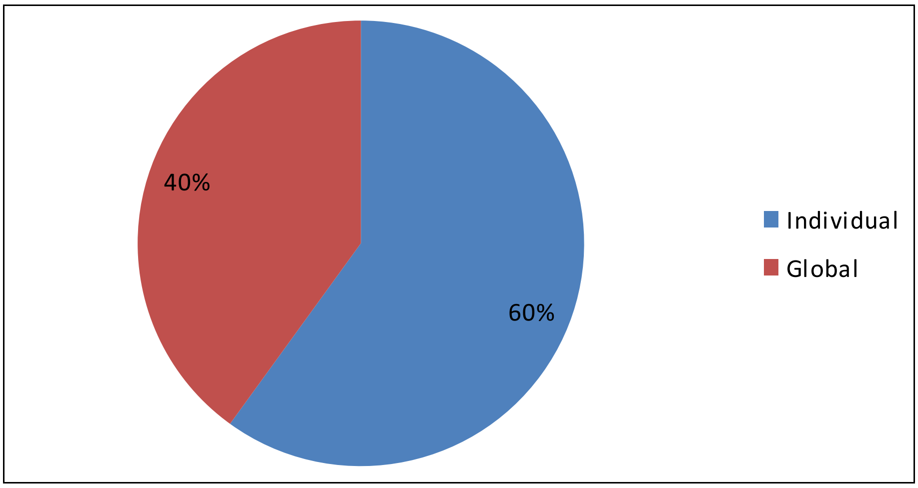


Figure 4.24. Frequency results of merged categories in the poster design activity of Pu2.

The nanotechnology product design ideas obtained from posters were listed in Table 4.34.

Table 4.34. Nanotechnology product design ideas.

	Pr1	Pr2	Pu1	Pu2
Nanotechnology Products	*"Borularda suyun kolay akması. - Increase the capacity of water flow through pipes"* *"Nanoteknoloji ile diş fırçalamayı ortadan kaldıracak bir sıvı. - A special liquid that eliminates the use of tooth brush"* *"Çok daha verimli benzin. - More efficient diesel"* *"Sümüğü burundan çeken selpak. - Selpak that removes mucus easily"*	*"Ojelerin çıkarılmasını kolaylaştıran aseton. - Increase the efficiently of acetone to remove nail polish"* *"Altı kirlenmeyen ayakkabı. - Soil release shoes"* *"Şampuan. – shampoo"* *"Yakıt tasarrufu sağlayan araba. - Saving fuel cars"* *"Havayı temizleyen fotobot. - cleaning air with fotobots"*	*"Şampuan. – Shampoo"* *"Her kapıyı açan anahtar. - The key that opens every door"*	*"Sprey düzeneği. - Spray apparatus"* *"Filiz Boya. - Filiz nano paint"*
Textile products	*"Perdelerin zor kirlenmesi kiri dışarda tutması. - Keep the curtains away from dust"* *"Gazdan enerji üreten iç çamaşırı. - Energy producing underwear"*			*"Nano kıyafet. – Nano clothes"*

Table 4.34. Nanotechnology product design ideas cont.

	Pr1	Pr2	*Pu1*	*Pu2*
Military/ Defense	*"Küçük bir operasyonla avuca gömülen bir dinleme cihazı. - A listening device that is hidden in palm of hand"*		*Şeffaf Kalkan. - Nanotürk Transparent shield: Nanoturk"*	*"Koruma. – Defense"*
Health	*"Anti depresanların ortadan kaldırılması. Elimination of anti-depressants" "Yemeklere konacak bir madde ile açlığın ortadan kalkması - Elimination of hunger by adding a substance to food" "Hareketsizliği azaltacak bir sıvı. - A liquid that reduces immobility" "Göz bozukluğunu ölçüp ona göre değişen polarize lens. - Special polarized lens that detects eye disorders and changes accordingly"*	*"Kilo aldırmayan çikolata. - Chocolate with no calorie" "Beyne yerleştirilen öğrenmeyi kolaylaştıran çip.- Nanochip that facilitates learning" "Nano sağlık robotları. - nano health robots" "Elektronik kalp. - Electronic heart"*	*"Nanoböcek. nano bugs" "Sağlık Kontrol Sistemi. -Health control system" "Doktorobot. – Doctorobot"*	*"Nanoptik. - Nano optic" "Nanoböcek Nano bugs" "Hastalıkları teşhis eden cihaz. - A device that diagnose diseases"*
Hi-tech Products	-	*"Nano araba lastiği. - Nano car tire" "Işınlanma. - Teleportation"*	*"Maddelere form veren mini-max teknolojisi. Mini-max technology that changes form of substances"*	*"Nanochip/32T B Naviglass. - Nanochip/32TB Naviglass" "Amorf Tanecikli Sıvı. - A liquid with amorf particles"*
Ethical/Political /Socio-economical issues	-	-	-	-

Some of students' poster designs of nanotechnology products were shown in Figure 4.25 to Figure 4.27.

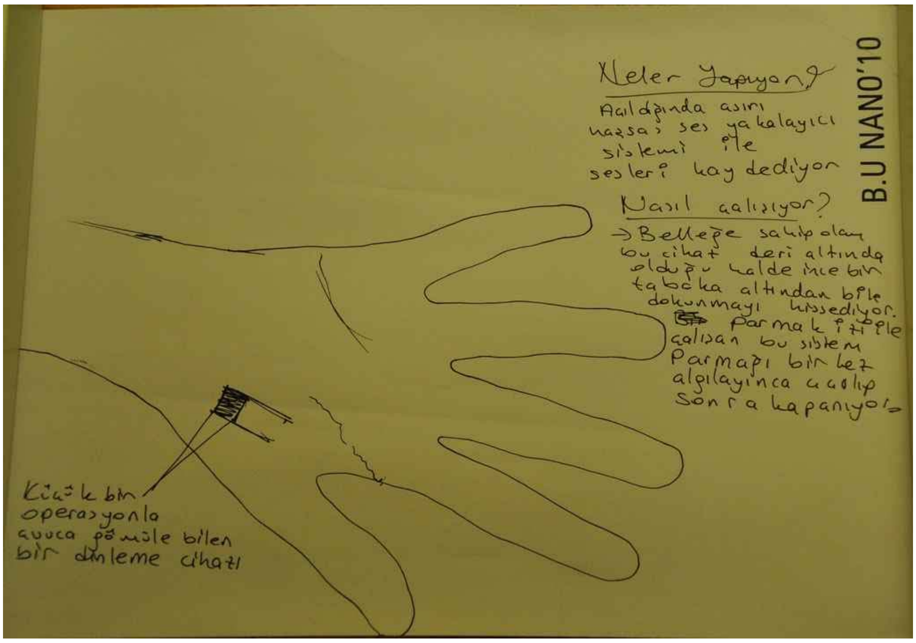


Figure 4.25. Nanotechnology product design ideas of Pr1.

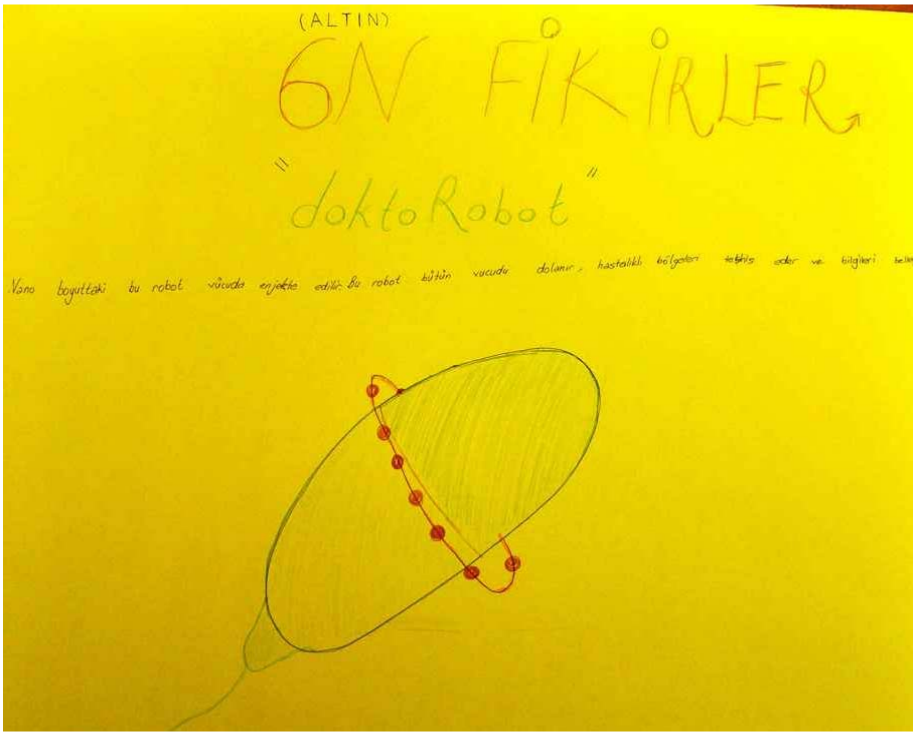


Figure 4.26. Nanotechnology product design ideas of Pu1.

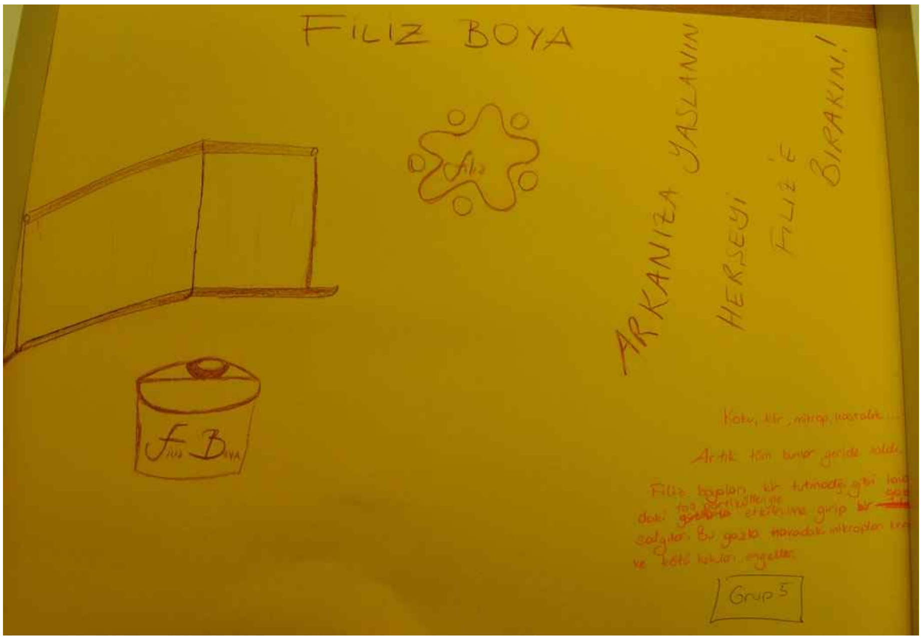


Figure 4.27. Nanotechnology product design ideas of Pu2.

4.3.4. Evaluation of the Workshop

Nanoscience and Nanotechnology Workshop Evaluation Questionnaire (NNWEQ) were given to all participants at the end of the workshop. Students answered ten open-ended questions for obtaining their evaluations about workshop by personal declarations after attending the workshop. Data obtained from NNWEQ was evaluated in quantitatively. Quantitative analysis was carried out individually for each group of students. The frequent distribution of data obtained from NNWEQ was calculated in the analysis of each category. The percentages of categories were calculated and evaluated separately for Pr1, Pr2, Pu1 and Pu2.

The collected data were read to define categories for each evaluation questions. The initial categories that were seen in the data also inform the codes that were used for a systematic analysis of the data.

In Question one, students were asked the question *"What was the most informative part of the workshop? - Atölye çalışmasının en bilgilendirici yanı neydi"* Students' answers were transcribed in seven categories which were "activities and experiments", "presentations", "examples", "microscopes", "use of nanotechnology areas", "nano textile products", "no answer". The frequency percentages of categories that students gave to the Question-1 were shown in Table 4.35.

Among all schools, the most frequent answer to the question-1 was "presentations". The percentages of the same answer given to this question were 55 % in Pr1, 41% in P2, 29% in Pu1 and 34% in Pu2 respectively. The second most frequent response was "activities and experiments"; 25% in Pr1, 29% in Pr2, 29% in Pu1 and 46% in Pu2. However, category of "microscopes" took place only in Pr1 with 10% and Pu1 with 7%. Category of "use of nanotechnology products" took place in Pu1 and Pu2 with 4 % and 7% respectively. The other category that only took place in two groups was "nano textile products" with the frequency of 6% from Pr2 and 9% from Pu2. The percentage of students did not give any response to the first question was 10% from Pr2 and 7% from Pu1.

In Question-2, students were asked the question *"What was the not adequately informative part of the workshop? - Atölye çalışmasının bilgilendirici olmayan yanı neydi?"* Students' answers were categorized into two categories which were "no, not exist" and "no answer". From Pr1, 33% of students responded as "no, not exist". The rest of the students from Pr1 gave no answer to this question. Response of students from Pr2 were equally distributed into two categories with 50%. Pu1 and Pu2 students gave responds of "no, not exist" more frequently than the respond of "no answer". The frequencies of "no, not exist" category were 64% and 72% with respect to Pu1 and Pu2. While, the percentages of the second category "no answer" were 36% and 28% for Pu1 and Pu2.

In Question-3, the question was *"What was the most impressive part of the workshop? - Atölye çalışmasının en etkileyici yanı neydi?"* The answer categories were "use of nanotechnology areas", "benefits and risks", "STM and AFM", "nano textile and water activity", "carbon nanotube", "no answer". For Pr1, most frequent answer category was "use of nanotechnology areas" with 28%, followed by the category of "nano textile and water activity". The rest of students' answers were distributed evenly to the categories of "benefits and risks", "STM and AFM" and "no answer" with 6%. For Pr2, the answer categories of "use of nanotechnology areas", "benefits and risks", "nano textile and water activity" took place in 6%. The highest frequency category was "no answer" with 17%. No response given in the category of “carbon nanotube”. For Pu1, most frequent answer was “benefits and risks”. The categories of “use of nanotechnology areas”, “nano textile and water activity”, “no answer” had the same frequency which was 11%. Similar to the Pr2, no response was given in the “carbon nanotube” category. In Pu2, most popular answer were “nano textile and water activity” and “benefits and risks” with 8%. The rest of the categories were distributed with same frequency, 4%.

In Question-4, students were asked to respond to the question of *“What is the most fun part of the workshop? - Atölye çalışmasının en eğlenceli kısmı ne idi?”* There were six categories of “nano textile and water activity”, “product design”, “hydrophilic and hydrophobic activity”, “activities”, “stain test activity” and “group discussions”. The most frequent response obtained from Pr1 was, “nano textile and water activity” with 44%, Pu1; for Pr2 “nano textile and water activity”, “product design” and “activities” were responded with same frequency, which is 17%. Popular answer among Pu1 students was “product design” with the 34%. It was followed with the answer categories of “nano textile and water activity”, “activities” and “group discussions” with 22%. Any of students from Pr2 and Pu1 gave answers of “hydrophilic and hydrophobic activity”, “stain test activity”. For Pu2, there were two popular categories with the same percentage. These categories were “product design”, and “activities” with 25%. The rest of the categories had the frequency of 13%.

In Question-5, students were asked the question *“What was the most boring part of the workshop? - Atölye çalışmasının en sıkıcı bölümü ne idi?”* Students’ answers were transcribed in five categories which are “presentation”, “filling out activity papers”, “long presentions”, and “no answer”. In Pr1, most of the students gave answer of “filling out activity papers”; 31%. In both Pr2 and Pu1, most frequent response was “presentation”; 36%, 49% respectively. In Pu2, this category had a 27%. “No answer” category for Pu2 has the frequency of 50%. The second highest frequencies with respect to schools were “presentation” for Pr1 and Pu2; 24%, 27% respectively, “no answer” for Pr2; 29%, “filling out activity papers” and “not boring” for Pu1; 19%. The third category “not boring” took place in Pu1 with 19%, in Pu2 with 14%, in Pr1 with 19% and in Pr2 with 0%. Answer of “questionnaire forms” given in only Pr1 and Pr2 with 7% and 14% respectively.

In Question-6, students were asked the question "*What are three things that should be removed from workshop? - Atölye çalışmasının içeriğinden çıkarılmasını önerdiğin üç şey nedir?"* Four different categories for the answers were labeled as "all parts should stay the same", "filling out the activity papers", "long presentations", and "no answer". Percentages of "no answer" category were the highest among other categories for all schools. For Pr1 and Pr2, "filling out the activity papers" category had the second highest frequency category; in Pr1 with 23% and in Pr2 with 14%. For Pu1 and Pu2, category of "long presentations" had the highest frequency. From the "all parts should stay the same" category, the frequency percentages were as follows: 8% in Pr1; 7% in Pr2; 14% in Pu1 and 5% in Pu2.

In Question-7, students were asked to respond to the question "*What are the things that should remain in the workshop? - Atölye çalışmasında mutlaka kalsın dediğin şeyler var mı, var ise nedir?"* For Pr1, the category of "activities" took 24%; "textile" and "video" categories took 18%; "presentation", "product design" and "discussions" categories took 7%. The lowest frequency belonged to "contact angle" with 3%. In Pr2, "textile activity" category took the highest percentage which was 31%. The category of "presentaion" took 13%. The categories of "activities" and "video" had 8%. The three category which were "product design activity", "contact angle activity" and "discussion" had the same frequency which was 6%. In Pu1, with 22% the category of "product design" took the highest frequency. It was followed by the category of "video" which had 21% frequency. The "presentation" category took 15%; "contact angle activity", "discussion" categories with 4% and the "activities" and "textile" took 7%. Lastly, in Pu2, "activities" category took the highest frequency; 41% then it followed by "textile" category with 23%. "Product design" had a 12%, "presentation" had an 8% and "discussion" had a 6%. The "contact angle activity" category was not mentioned by the respondents and took 0%.

In Question-8, the question was "*What would you wish to have in the workshop? - Atölye çalışmasında keşke olsaydı dediğin şeyler var mı, var ise nedir"* From all schools, the highest response frequency belonged to the category of "no answer"; 38% for Pr1; 67% for Pr2; 62% for Pu1 and 75% for Pu2. The category of "using electron microscope" got 26% in Pr1. 12% of Pr1 students stated that they would like to see "more details" in the workshop. Same students' responses showed that "seeing different nanotechnology products" and "seeing a real laboratory" had same response frequency of 6%. There was no response from the category of "seeing more in campus". In Pr2, the two categories which were "use of electron microscope" and "more activities" hold 13%. The category of "seeing different nanoproducts" took 7%. The other categories did not take place in responses of Pr2. In Pu1, "more details" category hold 16%. 7% of respond frequency belonged to the categories of "use of electron microscope", "seeing a real laboratory" and "seeing more in campus". The "seeing more nanoproduct activity" took 0%. The response frequencies of Pu2 showed that, "seeing more activities" category took 14%; "use of electron microscopy" and "seeing more in campus" categories took 5%. The other categories hold 0%.

In Question-9; students were asked *"Would you like to attend another nanoscience and nanotechnology workshop?- Bu atölye çalışmasından başka nanobilim ve nanoteknoloji ile ilgili başka bir çalışmaya daha katılmak ister miydin?"* Four categories of responds were found. These were "yes", "may be", "no" and "no answer". The highest response frequency was obtained from the category of "yes". The frequency percentage for Pr1 was 85%; for Pr2 was 66%; for Pu1 was 53% and Pr2 was 80%. From the category of "may be", only Pr1 students were responded with 5%. From the category of "no", the frequencies were found as 5% for Pr1; 10% for Pr2; 0% for Pu1 and 8% for Pu2. Addition to that, 5% of Pr1 students' didn't respond to this question. From Pr2 24% of students didn't respond. The highest frequency belonged to Pu1 with 47% and Pu2 took 12%.

In the Question-10 the question was *"What are your suggestions to improve this workshop and to make it more effective? – Bu atölye çalışmasını geliştirmek ve daha etkili kılmak için sizin önerileriniz nelerdir?"* The highest frequency belonged to the category of "no answer" with percentages of 52% for Pr1; 40% for Pr2; 63% for Pu1 and 43% for Pu2. For the categories of "longer break time", "no idea", "more visuals", "STM – AFM", "more activities", "shorter presentations" the frequency percentage was 8% for Pr1. The category of "seeing a real electron microscope" hold 20%, same with the category of "no answer". Two categories "more activities" and "it was good and effective" took 10%. The rest of the categories took 0%. 22% of students from Pu2 gave answers o "it was good and effective". 13% of them suggested having "more activities", 9% of them mentioned to have “shorter presentations” and “more visuals and “seeing a real electron microscope shared same percentages which were 4%.

Table 4.35. Evaluation of the workshop.

Question	Answer	Pr1	Pr2	Pu1	Pu2
Question 1: Most Informative Part of the NNW	Activities and Experiments	25%	29%	29%	46%
	Presentations	55%	46%	50%	31%
	Examples	10%	10%	0%	4%
	Microscopes	10%	0%	7%	0%
	Use of nanotechnology areas	0%	0%	7%	9%
	Nano textile products	0%	6%	0%	9%
	No answer	0%	10%	7%	0%
Question 2: Not Adequately Informative Part	No, not exist	33%	50%	64%	72%
	No answer	67%	50%	36%	28%
Question 3: Most Impressive Part	Use of nanotechnology areas	28%	6%	11%	4%
	Benefits and risks	6%	6%	17%	8%
	STM and AFM	6%	0%	0%	4%
	Nano textile and water activity	11%	6%	11%	8%
	Carbon nanotube	6%	0%	0%	4%
	No answer	6%	17%	11%	4%
Question 4: Most Fun Part	Nano textile and water test	44%	17%	22%	13%
	Product design	10%	17%	34%	25%
	Hydrophilic and hydrophobic activity	10%	0%	0%	13%
	Activities	17%	17%	22%	25%
	Stain test activity	10%	0%	0%	13%
	Group discussions	10%	49%	22%	13%

Table 4.35. Evaluation of the workshop cont.

Question	Answer	Pr1	Pr2	Pu1	Pu2
Question 5: Most Boring Part	Presentation	24%	36%	49%	27%
	Filling out activity papers	31%	7%	19%	23%
	Not boring	19%	14%	19%	0%
	Questionnaire forms	7%	14%	0%	0%
	No answer	19%	29%	13%	50%
Question 6: Should be avoided	All parts should stay the same	8%	7%	14%	5%
	Filling out activity papers	23%	14%	7%	9%
	Long presentations	0%	7%	29%	18%
	No answer	69%	72%	50%	68%
Question 7: Should stay	Activities	24%	8%	7%	41%
	Video	18%	8%	21%	0%
	Textile activity	18%	31%	7%	23%
	Product design	7%	0%	22%	12%
	Presentation	13%	6%	15%	8%
	Contact angle measurement	3%	6%	4%	0%
	Discussions	7%	6%	4%	6%
	No answer	10%	35%	15%	10%
Question 8: wish to have	Using electron microscope	26%	13%	7%	5%
	Seeing different nanotechnology products	6%	7%	0%	0%
	More details	12%	0%	16%	0%
	More activities	12%	13%	0%	14%
	Seeing a real nanotechnology laboratory	6%	0%	7%	0%
	Seeing more in campus	0%	0%	7%	5%
	No answer	38%	67%	62%	75%

Table 4.35. Evaluation of the workshop cont.

Question	Answer	Pr1	Pr2	Pu1	Pu2
Question 9: wish to attend further workshops	Yes	85%	66%	53%	80%
	May be	5%	0%	0%	0%
	No	5%	10%	0%	8%
	No answer	5%	24%	47%	12%
Question 10: any ideas to develop and redesign the workshop	Longer break time	8%	0%	6%	0%
	No idea	8%	20%	0%	0%
	No answer	52%	40%	63%	43%
	More visuals	8%	0%	0%	4%
	STM - AFM part	8%	0%	0%	4%
	More activities	8%	10%	18%	13%
	Shorter presentations	8%	0%	6%	9%
	It was good and effective	0%	10%	6%	22%
	Seeing a real electron microscope	0%	20%	0%	4%

4.3.5. Analysis of Interviews

As it is mentioned in the previous sections, there were semi-structured pre-interview and post-interview protocols, which consisted of questions that aimed to measure students' awareness, views and basic knowledge on concepts of nanoscience and nanotechnology. This instrument was used to obtain more detailed information in comparison to the paper-pencil NNAQ and NNCUQ instruments result. While Pre-interviews were conducted a week before the workshop, post-interviews were conducted few weeks after the workshop (See Table 3.6). Interviews as a qualitative data collection strategy were used to acquire in depth information.

Descriptive statistics are given related to the qualitative data collected from pre-interview and post-interview protocols. Frequency distribution of the answer categories were analyzed and compared with each other. Some of the categories will be exemplified by selected student responses. Student responses given for each interview questions were organized question-by-question.

The data gathered from semi-structured pre-interview and post-interviews were transcribed and read cautiously three times. Two students were selected from Pu1, Pu2, Pr1 and Pr2 for the interviews. Pre-interviews were conducted with 8 students so that, Post-interviews were conducted with same 8 students. As a result, 16 interview transcriptions were completed. The collected data were read with an eye for themes, categories, patterns and relationships for each interview questions. The initial themes and categories that were seen in the data also informed the codes that were used for a systematic analysis of the data.

Analysis of the qualitative data were facilitated by organizing the data in columns of a table that could be sorted by respondent ID number, question number, response and code that assigned during the analysis. For each response; ID number, question number, response were entered. When all questionnaire responses have been entered, the information was sorted as it was needed. For example, the column of question number was sorted so that all the responses to each question were obtained together. Then coding and analysis of data question by question were done. A set of codes were developed using both codes that were predefined and ones that emerge from data. Identifying these, the codes were added to table for each response. Coding was done in order to gain understanding of how respondents perceive nanoscience and nanotechnology. Coding also helped to reduce data into smaller groups; so, it helped to see relationships between the categories and patterns.

Data were also reviewed by an expert who was the thesis advisor and a graduate student in science education who also actively participated as a mentor in development and implementation of NNW. This allowed for different perspectives on the data. To test the inter-rater reliability, the raters determined which category each student responses fell into and then the percentage of agreement between the raters was calculated. The raters agreed 9 out of 10 times, and then the inter-rater reliability of the test had 90% of inter-rater reliability rate. As a result of comparisons, the coding categories of all data were modified and took the last form.

The frequency distribution of data obtained from pre-interview and post-interview instruments were calculated in the analysis of each category.

4.3.5.1. Pre-Interview Results. Starting with each pre-interview question, the coding categories are as follows:

In Question- 1, students were asked the question *"Kendini kısaca tanıtır mısın?.-Can you introduce yourself?"*

In this question only, no categories were coded since all the students were introduced themselves by stating that they were studying science and they were in 11th grade.

In Question- 2, students were asked the question *"Gelecekte hangi alanda çalışmayı düşünüyorsun? - In which field would you choose to work in the future?"*

The codes were "engineering", "arts and science" and "not sure". Students who would like to study in a department of engineering faculty gave answers as mechanical engineering, automotive engineering, and aerospace engineering. The coded category of "arts and science" consisted of physics, molecular biology and genetics, biology, sociology or psychology. Only one student stated that he did not decide on which field he would like to work in the future.

In Question-3, students were asked the question *"Nanobilim ve nanoteknoloji terimleri ile daha önceden karşılaştınız mı? Evet ise nerede karşılaştınız? - Have you heard about nanoscience and nanotechnology before? If yes, where did you hear them?"*

The codes were identified as yes "I have only heard" and "I have heard where…" There was one student mentioned that he only heard about nano as a scale, he could not give an example. Whereas, in the second category, students' answers revealed that, students heard about nanotechnology from various sources. These sources were clothes, science and technology magazine cover page, documentaries in television channels and internet. Only one student from Pr1 stated that he heard about nanotechnology from clothes that are used while doing sport.

"*Bir kaç kıyafette filan duydum sanırım, mesela …… vardı. Spor için, normalde çok küçük oluyorlar ama giyince babam bile giyebiliyor – I think I've heard a few clothes i.e. … had. For workout normally they have small sizes, but even my father can wear."*

Another student from Pu1 stated that he only heard about nanotechnology from science and technology magazine cover page, since he was not interested in science, he said he did not read and get information about nanotechnology.

"Nanoteknoloji terimi ile karşılaştım teknoloji dergi kapaklarinda görmüşümdür ama hiç ilgimi çekmediği için o isim böyle kimya ile ilgili şeyler, hiç araştırmada bulunmadım-I met with the term nanotechnology which drew my attention in technology magazine covers, yet I did not make a research about it as it did not attract me."

There were two students who heard about nanotechnology from documentaries, television channels like Discovery Channel. In addition, there were two other students mentioned that they heard nanotechnology from science and technology magazines. There was one student from Pu2 heard about nanotechnology from both documentaries and science and technology magazines.

"Daha önce bu Bilim Teknik, Bilim Çocuk kitapları, dergilerinin kitaplarını okuyordum orada görmüştüm…/Bir de belgesellerde de görmüştüm. Discovery Channel'daki oradan tanıyorum birazcık- Earlier I saw when I was reading Science and Technology magazine. Additionally, I have seen in documentaries in Discovery Channel."

There was another student from Pu2 who heard about nanotechnology from internet sources. He also had acquaintance with nanotechnology from one video game he played a while ago. He could not remember the name of the game. He only remembered in that video game, there were clothes produced by nanotechnology.

The Question-4 was *“Nanobilim ve nanoteknoloji terimleri senin için ne ifade ediyor? -What does nanoscience and nanotechnology mean?”* For this question, four different categories were formed. These were “scientific”, “scientific with alternative fragments”, “nonscientific” and “no answer”.

There was only one student who stated that she could not define the terms of nanoscience and nanotechnology was from Pu1. The rest of the responds mentioned “small particles”, “small size”.

One student from Pr1 required the keyword of “nanoscale” to answer. The student described nanotechnology by telling that it was about the materials produced and applications done at nanoscale. His response was:

“Nano ölçekte yapılan icatlar, o düzeyde çalışan gereçler.-The nano-scale inventions run on that level.”

One student Pu1 just gave a rough explanation by saying that nanotechnology was about small things. It was in the category of “nonscientific”.

“Nanoteknolojinin küçük parçacıklarla ilgili birşey olduğunu biliyorum. - I know that nanotechnology is about small particles.”

Three students however, explained what they meant about saying “small” while they were giving explanations about nanoscience. One mentioned small particles as “atoms” and nanoscience as science that dealt with atoms, small particles. Nanotechnology as similar to nanoscience produces things with small sizes of matter.

“Nanobilim: tahminimce nano olduğu için, atomlarla uğraşan, maddenin en küçük haliyle uğraşan bilim dalı gibi, tarif edebilirim sanırım. Nanoteknolojiyani yine maddenin en küçük haliyle birşeyler yaratan çalışma.-Nanoscience: my guess nano a branch of science deals with atoms, the smallest form of matter. Nanotechnology uses this smallest form of matter to create something.

The other student mentioned "small" as things that can be seen by microscopes. Based on these, nanotechnology was described as a type of technology that is created by the help of nanoscience.

"Anladığım kadar ile ufak şeyler işte. Nasıl açıklayablirim? Mikroskopla görülen. Nanoteknoloji ise Nanobilim ile geliştirilen bir teknoloji - To my understanding small things which can be seen with microscope. Nanotechnology is a technology developed using nanoscience."

The other student said "small" was related to chips.

"*Nano sanırım küçük seylerle ilgili. Büyük ihtimal çip tarzı şeylerdir - I guess related with small things, most possibly they are something like chips"*

Only one student gave nano scale as 10^{9-}. In explanation, small robots that would use in ate of medicine; military that would effect on people's lives were mentioned.

"On üzeri eksi dokuz değil mi, o derecedeki parçacıkların işte tıbbi alanlarda askeri alanlarda ve daha alanlarda alet için kullanılması nanobilim deyince aklıma şey geliyor küçük küçük robotlar gibi insanların sistemini etkileyecek birşeyin yapılması geliyor aklıma. – Particles of minus ninth power of ten used in medical military and other applications. Nonoscience reminds me small robots that will affect people's lives.

One student's answer differed from the others since he mentioned the practical issues of nanotechnology. He stated that nanotechnology enables to change size of materials make them smaller while keeping their functions. This way, the use of materials would be more practical. He also gave an analogy between concentrated detergents and nanotechnology products.

"Nasıl anlatayım hani şimdi deterjanları konsantre yapmaya başladılar ya bunu da onun gibi düşünüyorum hani daha maddenin daha en ufak haline kadar inip daha büyük birşeyi daha ufak daha pratik bir şekilde halletme daha az yer kaplıyor gibi bir şey – I

think of it as concentrated detergents. It is like something goes to its smallest state and it becomes more practical as it takes up less space.

In Question-5, students were asked "*Nanobilim ve nanoteknoloji hakkında neler biliyorsunuz, Bu konuda bildiğiniz güncel araştırmalar var mı? - What do you know about nanoscience and nanotechnology? Do you know some of recent research about this subject?"*

The categories obtained were "No, I haven't heard before", "I have heard some news about nanotechnology", "I know some old news about nanotechnology".

There were three students who had not heard any news about nanotechnology before.

One student reminded news that was about a material that can take the advantage of quantum energy would be related to nanotechnology. But, she was not sure about that.

Another student reminded Discovery Channel news that was about small things that put into human body. He could not remember the details.

From the category of "I heard some news", one student stated that he was a swimmer. So, he had knowledge about the swimming suit that was produced by using nanotechnology. In the design of this swimming suit, shark skin was imitated. The same student also gave example of chips that may be used in robots. Two students gave examples from the past.The examples given were related to military and health.

"Şu anda bilmiyorum birkaç senedir ilgilenmedim de daha önceden biraz ilgileniyordum. Yani hatırladığım askeri alanda çalışmalar var tehlikeli olacağını düşünüyorlar insanlar için tıbbi alanlarda çalışmalarını biliyorum yani biraz artık insanların mesela endoskopi için bu kullanılabilir bir teknik tıbbi anlamda çok iyi bir teknik. - I do not know, I haven't interested for the last years, I was a little bit interested previously. As far as I remember, there were efforts in the military field that would be dangerous for humans. I know some medical studies, for example it might be used for endoscopy which is very good method."

The last interviewee also mentioned that from several internet sources he gained some information about the use of nanotechnology laboratories in some countries.

"Aslında şöyle hani bir sürü ülkenin bunun üzerine çalıştığını işte bazı büyük ülkelerin laboratuarlar kurduklarını biliyorum da ne çalışmalar, internette karşılaşıyordum veya duyuyordum hani oralardan aklımda kalmış ama ne üzerine çalıştıklarını yani neler geliştirdiklerini en azından bilmiyorum. – I know that many countries work on this subject, some large countries established laboratories for studies as a have seen on the internet. Yet, I don't know what they work on and what do they develop."

In the Question-6, it was asked *"Nanoparçacık, karbon nanotüpler, STM ve AFM terimlerini sizin için ne ifade ediyor? Daha önce karşılaştınız mı? - What do you know about nano particles, carbon nanotubes, STM and AFM? Have you heard them before?"*

The themes of the question answers were categorized into two categories which were "no, I didn't hear before" and "I only heard about nano particles". Six students responded that they didn't hear about nanotechnology before.

The rest of the students only gave some explanation about nano particles.

One student explained nano particle as the smallest particle. She mentioned that she did not hear the terms of carbon nanotubes, STM and AFM.

"Nano parçacık, en ufak parçacık, diğerleri yok duymadım – Nano particle is the smallest particle, I didn't hear about the others."

The other student stated that nano particle was something related to 10^{9-} scale. He also mentioned he didn't know the other terms.

In the question -7, students' awareness about benefits and risks of nanoscience were questioned. The question was *"Nanobilim ve nanoteknoloji hangi riskleri ve faydaları beraberinde getiriyor? Bir vatandaş olarak bu konuda yeterli bilgiye sahip olduğunuzu* *düşünüyor musunuz? - What are the benefits and risks of nanoscience and nanotechnology? As a citizen, do you think that you are knowledgeable enough?"*

Except one student, six of the interviewees responded from the category of "only benefits" and two responded from the category of "both benefits and risks". Among those students, only one student did not give an example for the benefits. He only pointed out that nanotechnology should have benefits for technology. He responded as follows:

"Bir risk getirdiğini düşünmüyorum ama teknolojik olarak illaki bir faydası vardır. – I don't think that it brings any risks. However, I believe that it certainly has technological benefits."

In other responds, the benefits of nanotechnology were revealed as its benefits for producing more durable and efficient products especially military equipments such as bullets, improving health technology to overcome diseases like tumor easily, enable us to do things in microscopic scale. Two students pointed out the benefits about human health. One student stated the benefits about military. The respond that was about military is here:

"Yapılan şeylerin eşya olsun, kıyafet olsun, daha dayanıklı daha verimli daha çok alanda kullanulabilir şeyler olmasını sağlayabilir. Savaşta kullanılabilir diye tahmin ediyorum. Kullanılan her teknoloji sonuçta kullanılıyor askeriyede o yüzden belki merminin daha verimli daha fazla hasar vermesini sağlayacak birşeyler yapılabilir. – It might make things be goods or clothing to be more efficient, used in many areas and be more durable. I guess that can it can be used in battles. Ultimately every new technology is used in military, so projectiles might be more efficient to give more damage."

Two responds that were about human health were:

"Riskleri konusunda şuan birşey söyleyemiyorum da yararları insan sağlığı ile ilgili çok büyük yararları olabileceğini düşünüyorum ama, vücuda girerse ne bileyim tümörün nerede oldugunu daha net bulabilir diye düşünüyorum. - I can not say anything at the moment about the risks and benefits but I think it might be very useful for human health. I think it can find the tumor's place more accurately."

"Bilim ve teknolojinin mi, yani yararlar olarak insanların hayatını daha da kolaylaştırabilir. Mesela en önemli şey olarak sağlık, tıpta ilerleme insanların sağlığı için. Mesela eskiden insanlar çok daha kolay hastalıklar için ölebiliyorlarmış ama şimdi daha da mesela kanser falan onunla ölebiliyor. – It can make people's life easier. For example, the most important thing is health, progress in medicine for people's health. For example, people in the past died from simple diseases, but today many die from cancer."

One possible risk stated as decrease of amount of human work, decline in human work capacity. In other words, it would reduce the efforts of human being to work.

"Bilim kötüye kullanılabilir. Geliştirilen herşeyin yan etkisi de oluyor. Zarar olarak da şöyle kolaylaştırıyor kendi çabamızı azaltıyor çok ilgi uyandırmıyor. Olmam gerekir ama yeterli bilgiye sahip değilim. - Science can be exploited. Every development leads to side effects. It makes it easier and makes it more effortless reducing our interest. But I do not have enough information."

From two students who gave answers for both benefits and risks, first student exposed that nanotechnology could ease people's life; however at the same time it brings some risks. These risks were about production of weapons, shielding clothes, nano things that may attack. This student also mentioned that he has not enough knowledge about nanoscience and nanotechnology. He also compared himself with the society. Although he found himself more knowledgeable than the rest of the society, he still felt that he was lack of enough knowledge on this subject.The other student gave answers for both benefits and risks described that the risks would be in the area of military, whereas the benefit would be about practicality that nanotechnology would bring to people's life. One example was:

"Daha çok askeri alanda bu teknolojiyi geliştireceklerini düşünüyorum çünkü insanlar hani bütün devletler kendilerini savaşa hazırlıyorlar veya dışarıdan gelecek tehlikelere karşı korumak istiyor böyle yeni bir teknoloji buldukları zaman da hani en azından deneyecek yani askerlerin üzerinde bakalım etkisi nasıl olacak daha iyi bir asker olacak mı diye bence bu zararı olur. Günlük hayatta pratik olarak çok fazla şeye yardımcı olabileceğini düşünüyorum ben en azından eğer geliştirilirse bazı şeyler. - I think more to develop this technology in the military field. Because of the people and the states are

preparing themselves to war, or they want to be protected against threats from outside. They will try, at least when such a new technology is developed. So they will look at the impact on the soldiers. I think that would be the loss. I think in practice it can help so many other things in daily life, at least some things will be developed."

In question -8, students were asked *"Nanobilim ve nanoteknoloji hakkında ne merak ediyorsunuz? Ne öğrenmek isterdiniz? - About what aspect of nanoscience and nanotechnology are you curious about?"*

Two categories were formed. These categories were about being curios or not about nanoscience and nanotechnology. Categories were "not curious about nanotechnology", "curious about nanotechnology".

From the first category, there was only one answer. One stated that he was not curious about things relate to technology. From the second category, the answers varied according to interviewees. The first interviewee was curious about how to obtain a nano particle, what to produced and developed by nanotechnology, the laboratory environments. The second student said he was curious about definition, application areas, benefits and risks, especially learning the basis of nanotechnology.

"Öncelikle tanımı hangi alanlarda kullanılıyor, yararları zararları, en azından temelini ögrenmek işime yarar. - First, the definition, areas it is used in, losses and benefits. At least I could learn the foundation."

Another student was curious about the connection of genetics and nanotechnology, especially the subject of stem cells.

In another response, students said they would have liked to learn about what nanotechnology with application areas, benefits and risks, its place in their lives.

One other respondent included that he would have liked to learn why nanotechnology was used to produce weapons. He would have liked to learn about harms that would have been given to people. He also added that, taking answers to such questions was the reason to attend this workshop. His response was:

"Teknoloji hakkında silah yapımında ne için kullanıldığını öğrenmek isterdim, daha çok insanlara vereceği zararları düşünmek isterdim. Yani benim amacım bu, çalışmaya girme amacım. Bunları merak ediyorum. - I would like to learn about how technology is used for making weapons. I wish more people think about the harmful effects. So it is my intention to enter the study."

The Question -9 was, *"Nanobilim ve nanoteknoloji hakkında okulda bir ders almayı ister miydin? Ya da bir dersin içerisinde öğrenmek ister miydin? - Would you like to take a nanotechnology course at school? Or would you like to learn about nanotechnology in your science lessons?"* The response categories were formed as "No, not would like to attend such courses", "Yes, I would like to attend such courses". There was only one student said no. He mentioned that, he was not interested in science in general. The answers from the category "yes" had some detailed explanation.

First student said he had not attended such activity before and he added that it would be interesting for students. Another student shared that he would also like to take nanotechnology courses at school, he also added that he was already curious about nanotechnology and would like to search more about nanotechnology at home.

The other interviewee also added that since nanoscience was about science, he would have liked to be informed more about nanoscience. He also stated that getting information about nanoscience would enable them to learn where to use and how to use it and learn the possibilities of integrating nanoscience to other work areas. Attending such a course considered as useful to get information about benefits of nanotechnology.

"Evet yani yeni bir şey sonuçta bilimle ilgili isterdim: İşte nerelerde kullanıldığını biliriz, biz ilerde işte iş alanlarımızda bunları şey yapabilir miyiz?, kullanabilir miyiz? bilmek ne kadar yararlıdır bizim için böyle şeyleri?. - Yes, something new about science that I wish: Here we know where they can be used. Can we use them in our fields we work in the future? How useful to know such things for us."

One student looked through a different perspective. He mentioned that, in public schools there were not enough facilities such as science laboratories already. He thought that having a nanoscience workshop was impossible since schools' infrastructures were inadequate. Therefore, he suggested integrating nanotechnology into science courses.

"Yani okulun altyapısı yetmez ki. Yani ülkemizdeki devlet okullarının laboratuarımız yok yani nanoteknoloji atölyesini nasıl yapacağız? Dersin içeriğinde olmasını isterdim. - So the school does not have enough infrastructures, there is no laboratory in public schools. How would nanotechnology laboratories are build in schools? I wish that nanotechnology was in course content."

The last interviewee shared his opinion about taking nanotechnology courses at school. He said taking such courses would be helpful although it would not be an easy course compare to other courses they took at school.

"Aslında iyi olur o kadar saçma dersler görüyoruz ki belki ağır gelir ama ilk başta bir süre sonra alışırız. - "In fact, we see many absurd courses. Perhaps, it might be difficult at first, but after a while you get used to at first".

In the Question -10 expectations of students about the NNW were asked *"Bu atölye çalışmasından beklentileriniz nelerdir? - What are your expectations about this workshop?"* According to the responses, two categories coded as "I have no expectations", "I have some expectations such as…"

Out of eight students, only two students answered that they had no expectations from the workshop. First student gave the reason as having no information about nanoscience and nanotechnology. Second student shared his curiosity and mentioned that he was a volunteer attending this workshop.

The answers from the second category which was "I have some expectations such as…" varied among the interviewees.

One student from Pr1 stated that he was interested in seeing microscopes. He also guessed that the workshop may require activities about nano fabrics.

One student from Pr2 and one student from Pu1 shared similar expectations as spending time and learning new things in a laboratory of a prestigious university. Student from Pu1and Pu2 mentioned that they were willing to learn more about new technological developments happening in the world. The student from Pu1 also added that learning technological development would also increase his awareness. The student from Pu2 also told that attending this workshop would affect some of students' decision on future work areas, may be few of them would choose to work in areas related to nanoscience and nanotechnology. Another student from Pu2 shared his interest to learn about technological developments and applications especially in Turkey. One selected response from Pu1 student was:

"Evet, gönüllü oldum. Çünkü merak ettim sonuçta bir yerlerden birşeyler duyuyorsun ama ne olduğunu bilmiyorsun merak ettim, öğrenmek istedim. İşte dediğim gibi hayatımızda nelerde var mesela bizim bilmediğimiz belki de birçok şey de vardır. Onları bilmek, daha bilinçli olmak, ona göre davranmak tabi.- Yes, I volunteered. Because, you heard about things that you ultimately do not know. I was curious about it and would like to learn about it. Here's what's on in our lives, for example, as I said there are many things we do not know, perhaps. Knowing them, become more conscious and subject to act accordingly".

In the last question, students were asked whether they had additional things to add to this interview. *"Sizin de eklemek istediğiniz birşey var mı? - Would you like to add something?"*

Out of eight students, six of them said "No, thanks". However, one student from Pr2 and other student from Pu1 shared similar opinions. They suggested that it would be better to have nanotechnology activities in their schools before they visited the university.

4.3.5.2. Post-Interview Results. Post-interview questions included twenty questions which consisted of pre-interview questions, Nanoscience and Nanotechnology Workshop Evaluation Questionnaire (NNWEQ) and few additional questions to get more detailed information about students' views on the workshop. The results obtained from the responds to these questions will be compared to pre-interview responds and NNWEQ responds and the similarities and differences will be discussed in the discussion chapter.

Similar to the pre-interview questions, for each question answers were coded and categorized.

In Question-1, students were asked the question *"Nanobilim ve nanoteknoloji atölyesine katılmış olman, nano ile ilgili kavramları anlamanı arttırdı mı? - Does attending Nanoscience Workshop increase your understanding of nano related concepts?"* The only answer category that was obtained was "Yes, attending workshop increased understanding about nano". Four students, two from Pu1 and the other two from Pu2 gave similar responds. They mentioned that, before attending the workshop, they had almost no ideas about nanotechnology, whereas after workshop they gained new information about nanotechnology. Addition to that answer, student from Pu1 told that the presentations and activities led them to get informed about basic terms of nanotechnology. Pu2 also pointed out that they learnt new things by doing activities. From the Pr1, two of the students mentioned that they learnt about different applications in the field of nanotechnology. In Pr2, one student responded that he had some basic knowledge about nanotechnology before the workshop; he also learnt new things and increased knowledge of nanotechnology. The other student from Pr1 also gave some examples of nanotechnology application that were discussed in the NNW. The applications were about technologies of war, stain-resistant clothing and things in the medical field. The respond was as follows:

"Genel olarak nanoteknolojinin hangi alanlarda çalıştığını anlamamı sağladı özellikle genel katkısı o oldu. Mesela savaş teknolojileri tekstil tarzı şeyler hani kıyafetti leke tutmayan şeyler, tıp alanındaki şeyler. - In general, the overall contribution of nanotechnology in particular that helped me understand what working areas of nanotechnology are. For example, war technologies, like textile style stuff like stainless clothes, things in the medical field."

The second question was "*Nanobilim ve nanoteknoloji terimleri senin için ne ifade ediyor?- What does nanoscience and nanotechnology mean?*". Same question was asked in the pre-interview too. It was repeated in the post-interview to see whether there was any conceptual change or not. The categories formed in pre-interview were also used in the post-test. These categories were "scientific", "scientific with alternative fragments", "nonscientific" and "no answer".

For this question, there were no answers from the category of "no answer". For the other three categories, there were some similarities. Each respond mentioned "nano particles" as small particles. They used the term "nano particles" in their definitions. There were two answers, one taken from a student of Pr2 and Pu2 described nanoscience and nanotechnology separately. These two answers placed in the category of "scientific with alternative fragments". The Pr2 student responded as nanoscience is the field of science that is about nano particles. Add to this, the same student described nanotechnology as the technology that uses nano particles.

"Nanobilim yani ufak parçacıklardan oluşan bilim. Nanoteknoloji parçacıklarla yapılan teknoloji. - Nanoscience the science of small particles. Nanotechnology is technology that created by particles."

The other answer from this category was from Pu2 student as nanoscience was the field of science that investigates nano particles whereas nanotechnology was about the application of nano particles such as stain-resistant fabrics.

"Nanobilim herhalde yani nano boyuttaki parçaları araştıran bilim dalı.- Nanoscience probably researching the science of nano-sized pieces."

"Nanoteknoloji de o bilimin çıkardığı şeyler uygulama gibi... O gördüğümüz kumaşlardaki şeyler gibi falan olabilir mesela. - Nanotechnology is the things like the application of science…For instance, it might be something that we saw in such fabrics"

The other Pr2 and Pu2 students also mentioned about nano particles as nano-sized particles. However, they did not explain nanoscience and nanotechnology separately. One example response was:

"Nano boyuttaki parçacıklar ile yapılan araştırmalar. – Research on nano-sized particles"

Two of the other students from Pu1 explained nanotechnology by only giving an example that they learnt in NNW. Their answers were placed into the category of "nonscientific". The examples were about nano-fabric applications and nano sprays that enable water-resistant surfaces.

In Question-3 was asked *"What nano-related concepts did you understand? - Nanobilim ile ilgili hangi konuları daha iyi anladın?"*

The answer categories were formed as "applications", "applications with examples", "no answer"

From Pr1, both students responded as daily life applications. They did not mention specific examples. Their answers placed in the category of "applications". Pr2 students' answers were placed in the category of "applications with examples". First student of Pr2 gave the examples from the activities done in NNW related to hydrophobic property; "water drop activity" with leaves, nano material coated napkin. One interviewee from Pu2 also mentioned the "water drop activity" in which water stayed on the hydrophobic surface in shape of a drop. Second student of Pr2 gave example of nano robots and applications that take inspirations from nature. One of Pu1 student also gave example of water-resistant materials and nano-sprays for coating a surface and makes it water-resistant. She also said that, after attending NNW and gaining information about its daily use applications, she bought a nano-spray for her shoes. The other student from Pu2 gave examples of military clothes that are durable. Only one student from Pu2 responded as "I do not remember".

One new question was asked as the fourth question *"Which nano-related concepts challenged you? - Nanobilim ile ilgili hangi konuları anlamakta zorlandın?"* The categories formed were "didn't have difficulty, everything was clear", "I had some difficulties where…".

Out of eight students, three students from Pu2 responded that everything was clear in NNW. From Pr1, first student mentioned information about the process of production of new materials, how to do applications in nanotechnology were not informative enough. The second student also pointed out that information about production of nano materials and how these materials were used in nanotechnology were incomplete. From Pr2, one student said information given from videos about electron microscope and AFM were exceeding their understanding since they were in advance level. The other student of Pr2 stated that he did not understand the terms such as "bucky ball". One student from Pu1 said that he had difficulty to understand Richard Feymann's saying "W*hy cannot we write the entire 24 volumes of the Encyclopaedia Brittanica on the head of a pin?"*

In the fifth question, students were asked *"Nanobilim ve nanoteknoloji konusu hakkında aklında kalan Nanobilim ve Nanoteknoloji araştırmaları var mı? - Are there any research studies that remain in your mind?"* Two answer categories were found. One was "nothing", the other was "I remind some examples such as…" In the answer category of "nothing", two answers were placed. One from student of Pr1 and the other from student of Pu2. The rest of the students gave examples that they kept in mind. The other student of Pr1 said research relate to microscopes were interesting. From Pr2, one student mentioned nano suits as an example. The other Pr2 student gave a general answer as daily life applications. From Pu1, both students gave similar answers. One other Pu2 student also shared the same answer. The answer was about the short film "The Man in the White Suit" that was shown at the beginning of the NNW introductory presentation. In that film, the main character was the researcher and making research about a new fiber. One sample respond was given as follows:

"Aklımda kalan araştırmalar beyaz elbiseli adam diye bir şey hatırlarsınız Film O gerçekten çok şeydi sizin onun hakkında yaptığınız araştırmalarda çok eski tarihlere dayanmasına rağmen gerçekten çok ilgi çekiciydi. - Remember one thing which was about the man in white suits. Although the research you done about that movie was form old times, it was still really interesting."

In the question 6, it was asked *"Sizce Atölye Çalışmasının en bilgilendirici yanı neydi? - What was the most informative part of this workshop?"* This question was also asked in NNWEQ. The categories were "all informative", "the informative part was…"

One student from Pu2 stated that NNW was informative as a whole. The respond was:

"En bilgilendirici… Sonuçta yaşadığımız zamanda çok önemli bir bilim hepsi bilgilendiriciydi ve hiçbirşey bilmeyen bir insan için çok iyi bir çalışmaydı. – The most informative…it is one of an important field of science in our century and it was a great study for the ones who do not know anything"

The rest of interviewees gave different responses. Pr1 students found application examples informative. First student said the part that the microscopes were informative. Second student said nano textile part was informative. From Pr2, one student mentioned about benefits and risks discussed in NNW were informative. He gave details as applications in health for benefits and military for risks. Second student from Pr2 said applications and their use areas. No specific example was given. From Pu1, both students revealed that activities conducted in NNW were the most informative parts. Second student from Pu1 also added that activities part were the most informative since they had a chance of learning by doing. One of Pu2 said presentation parts were informative.

The Question -7 asked *"Sizce Atölye Çalışmasının en etkileyici yanı neydi? -What was the most impressive part of this workshop?".* According to the responses, the categories obtained were "nothing", "the exciting part was…" and "all".

One student from Pr1 found nothing exciting in the workshop. This answer formed the category of "nothing". In addition, there was one student from Pu1 found all parts of the NNW interesting. The rest of the students' answers varied. The other student of Pr2 found Lotus effect interesting. Two more students from Pr2 and Pu2 shared same interest. They also gave example of Lotus effect. The student from Pu2 stated the similarity of Lotus flower and nano textile products. The gecko example also found very interesting by Pr2. The other student from Pr2 found nano-coated napkin activity interesting. From other interviewee of Pu1 the respond was taken as nano-coating examples. This student also mentioned that he saw nano-coated textile advertisements on TV after attending NNW.

In the Question-8, students were asked *"Bu atölye çalışması nanobilim ve nanoteknoloji ile ilgili görüşlerinde nasıl bir değişime sebep oldu? - Does this workshop make any changes in your views about nanoscience and nanotechnology?"*. "Knowing wide range of application areas", "being more knowledgeable about nanotechnology" were two of the categories obtained from this question. Two students from Pr1 mentioned that attending NNW gave them opportunity to realize different application areas of nanotechnology. The rest of the students stated that attending NNW increased their knowledge about nanotechnology. As an example to the responses given for this question was:

"Yarattı, ben çünkü daha önce bir film izlemiştim onda da nanoteknoloji kullanılıyordu ama çok ufak böyle. İsmini hatırlamıyorum ama çok ufak çaplı çipleri kullanarak onu da yapıyorlardı. Ben hani sadece o şekilde o tarz bir şey sanıyordum. Halbuki çok geniş bir alanmış. - Yes, indeed, because once I watched a movie, where a little in it was used the nanotechnology. I do not remember the name, but they were doing nanotechnology by using a very small-scale chips. I thought that nanotechnology was only about that kind of things. However, it is a very rich field of science".

In the Question 9, the question was *"Nanoparçacık, karbon nanotüpler, STM ve AFM terimlerini sizin için ne ifade ediyor? - What do nanoparticle, carbon nanotube, STM and AFM mean?"* This question was asked in also asked in NNCUQ and pre-interview. "Don't remember anything", "only remember some of the terms".

From the category of "only remember some of the terms", the answer of students varied. One student from Pr1 only defined nanoparticle and carbon nanotube. He stated that he could not remember STM and AFM. Second student from Pr1 gave similar definitions to nano particles and carbon nanotubes as the first student of Pr1. They defined nano particles as nano sized particles. They also defined carbon nanotubes as cylindrical shaped structures. The second student from Pr1 could also define STM and AFM as microscopes used in nanotechnology. From Pr2, first student defined nano particles as small particles without mentioning how small they were. She could not remember carbon nanotubes and STM and AFM. Second student from Pr2 tried to explain how small nano particles were. However, he could not remember how small they were. He could not remember carbon nanotube too. He tried to explain the difference between STM and AFM. However, he could not remember which one was about scanning with a prope from a short distance and which one was about touching the surface with a sharp prope gently. The student from Pu1 tried to describe nano particles with nano factor 10^{-9}. However, he could not remember. Carbon nanotube was described with its cylindrical form. STM and AFM were described in details. For STM, it was stated that it was used for scanning the surface. For AFM, it was mentioned it was used for making some calculations. The other student from Pu1 could give a detailed and scientific explanation about nanoparticle. Nanoparticle defined as small particles with nano factor of 10^{-9}. It was also added that there are smaller particles than nano particles. Carbon nanotubes described with their property of being easily folded and their carbon structure. Their resistance also mentioned. STM and AFM were described as one was used for scanning the surface, the other was for touching the surface. One student from Pu2 could not remember anything. The second student from Pu2 defined nano particle with nano factor 10^{-9} correctly. However, carbon nanotube could not explain. About STM and AFM, they described as microscopes but no details were given. The quota that shows all the explanations of terms was the following:

"Nanoparçacık en küçük birim ama daha küçükleri de var. On üzeri eksi dokuzdu galiba. Karbon nanotüp o kıvrılabilen olandı değil mi? Dayanıklıydı ama şekil alabiliyordu. Dizilimi karbondu. STM AFM Onlar, biri yüzeyi tarayarak biri de dokunarak mı öyle Bir şeydi? - Nanoparticle is the smallest, but there are other smaller particles. I was ten to the power minus nine I quess.. Is not that carbon nanotube the one that can be bend? Tough but it could take shape. It was made up of carbon chains. STM, AFM; one by tapping, the other one of the scanning surface, isn't it?"

In the Question -10, it was asked *"Nanobilim ve nanoteknoloji hangi riskleri ve faydaları beraberinde getiriyor? - What are the benefits and risks of nanoscience and nanotechnology"*. This question was also took place in pre-interview. In the pre-interview, the answer categories were formed as "only benefits", "both benefits and risks". In the post-interview, the only category formed was "both benefits and risks". The answers of this question had similar benefits and risks. In Pr1, one student gave example to risks from the military field. “Invisibility” issue stated as risky. Same student gave medical field as example to benefits of nanotechnology. The second student from Pr1 also gave similar answers. The only differerence was, he did not specifically give example to risks, only mentioned that risks would be about military field. One student from Pr2 mentioned war technology in risks and medical field in benefits. The other student from Pr2 mentioned war in risks, and making life easier in benefits. In public schools, Pu1 students also gave examples to risks from military field, production of special weapons; health was given as example of benefits. The other student from Pu1 mentioned that risks and benefits could be about same field, such as medical field, health. According to the other student from Pu2, benefits were about textile industry and risks were about development of arms industry.

In the Question -11, students were asked *“Nanobilim ve nanoteknoloji hakkında ne merak ediyordun? Atölye çalışmasında öğrenebildin mi? - What were you curious about before the workshop? Were you able to learn about it during the workshop?”*

There was only one category obtained which was “I was curious about…” One of students from Pr1 was curious about application areas and processes of applying or doing nanotechnology. Pr2 answered similar, he was also curious about application part. In Pr2, first student was curious about nano itself, since she had no initial idea about nano related subjects. The other student from Pr2 was also curious about applications and impacts on our lives. In public schools, Pu1 students were curious about its applications. One of Pu2 students however, also mentioned that he would like to do some experiments in NNW and he did some during NNW. The other student from Pu2 revealed that he gained new information about nanotechnology after attenting NNW.

In the Question-12, students were asked *"Sizce Atölye Çalışmasının en az bilgilendirici yanı neydi? - What was the least informative part of this workshop?"*

Out of eight students, half of them answered from the category of "No, not exists"

From "the informative part was…" category, students' responses were varying. Similar to the previous answers of the student Pr1, the least informative part was how we apply this technology. The other Pr1 student also mentioned about the process of the applications, more technical parts. One student from Pr2, found NNW as very informative. But he also added that although NNW was informative, the information shared was a bit advance level. The other Pr2 student said there would be more examples related to application areas. First student from Pu1 found NNW very informative. She also added that the level of information given suited to high school students. The other student of Pu1 and two of the students from Pu2 shared the same opinion. They thought that NNW was informative enough.

The Question-13 was asked as *“Nanobilim ve nanoteknoloji hakkında okulda bir ders almayı ister miydin? Ya da bir dersin içerisinde öğrenmek ister miydin? - Would you like to take a nanotechnology course at school? Or would you like to learn about nanotechnology in your science lessons?”* In the pre-interview the categories were formed as “no, not would like to attend such courses”, “yes, I would like to attend such courses”. However, in the post-interview results it was revealed that there was only the category of “Yes, I would like to attend such courses”. Most of the students gave short answers like *“Olsa memnun olurdum. - I would be happy about that”, “Kesinlikle isterdim. - I would love to attend” “, Kesinlikle – Absolutely”.* .Only one student from Pr2 had a detailed suggestion. He suggested that, since their school was a small one, nanotechnology could better to be offered as an elective course. For crowded schools, he also suggested nanotechnology club activities.

In the Question-14, it was asked *"Bu atölye çalışmasından beklentileriniz nelerdi? Beklentilerini karşıladı mı? - What were your expectations about the workshop? Were your expectations met?"*

The categories were "No, expectations were not met", "Yes, expectations were met". Except one student from Pr2, the rest of the students' expectations were met. They suggested similar expectations such as learning about nanoscience and nanotechnology.

In the Question-15, students were asked *"Bu atölye çalışmasından sonra nanoteknoloji ile ilgili başka araştırmalar yaptın mı? - After this workshop, have you done other research about nanotechnology?”*

Out of eight students, three students did not make additional research about nanotechnology. Two of these students were from Pr1, one of the students was from Pu1 and the other student was from Pu2. Another student was from Pr2 searched for gecko from the internet at home. The second student from Pr2 searched for applications of nanotechnology from the internet. One student from Pu1 made research about nano textile products and also nano-coating materials. She also bought a nano-spray after NNW. Another student from Pu2 also mentioned the Internet search that was done about nanotechnology applications.

The questions from 16 to 20, same questions were asked at NNWEQ.

In question 16, students were asked *"Atölye çalışmasının içeriğinden çıkarılmasını önerdiğin şey var mı, var ise nedir? - Is there anything that you recommend to remove from the content of the workshop?"* The categories obtained from the answers were "Should stay the same", “The part that can be changed was…"

Four students, three of them from public schools and one from Pr2 said they enjoyed the NNW. They shared that all parts should stay same. From the second category “The part that can be changed was…" different answers were obtained. From Pr1, one student gave the answer of “scale activity” in which, different pictures were given to students and they were asked to put them in order. The other student from Pr2 stated that filling out activity papers should be omitted. From Pr2, first student explained that videos about electron microscope and AFM could be removed from the content. The same student mentioned that without videos the duration of workshop could be less. One student from Pu1 said video recording during the workshop could be omitted.

In the Question-17, it was asked *"Atölye çalışmasında mutlaka kalsın dediğin şey var mı, var ise nedir? - Is there anything that you recommend to keep within the content of the workshop?"* The answer categories formed were "hands-on activities", "nano-product design". The answers of the students pointed out the hands-on activities done during NNW. Only one student recommended nano-product design activity. From the answer category of "hands-on activities", first student from Pr1 recommended that “The Black Box activity” should stay in NNW. The other student of Pr1 and two students from Pu1 and one student from Pu2 gave a general answer as "all activities" rather than stating a specific example. One student from Pr2 gave detailed information about the hands-on activities suggested to remain in NNW. The quota was as follows:

“Daha çok videoyla değil de hani zaten deneyerek bizim de yaptığımız gördüğümüz şeyler o yaprakları, peçeteyi, kutuları, onlar mutlaka kalsın. –not seeing by video but the hands-on activities we saw and did like leaves, napkin, boxes…they must remain”

The Question-18 was, *"Atölye çalışmasında keşke olsaydı dediğin şey var mı, var ise nedir? - Is there anything that you wish to have within the content of the workshop?"* The answer categories obtained were "It was adequate", "no idea”, “I wish there was…" Three students stated that they had no idea. One student from Pu1 said the workshop was successful and enjoyable. Both students from Pr1 stated that they would like to see real microscopes. One student from Pr2 suggested adding some cartoons about nanotechnology. The other student from Pr2 recommended having more application examples. Another student from Pu1 said the break time between the sessions of NNW could be longer.

In the Question -19, students were *asked "Bu atölye çalışmasından başka nanobilim ve nanoteknoloji ile ilgili atölye çalışmalarına katılmak ister miydin? - Would you like to attend other nanotechnology workshops?”* Two answer categories were "Yes, I would attend" and "No, I wouldn't attend". There was only one student answer from the category of "No, I wouldn't attend". This student gave the reason as not having advance knowledge about nano. The other students mentioned that they would like to attend. Add to this, one student from Pr2 also suggested to have a discussion platform as a workshop about nanotechnology.

In the last question of post-interview, it was asked *"Bu atölye çalışmasını geliştirmek ve daha etkili kılmak için sizin önerileriniz nelerdir? - What are your suggestions to make this workshop more effective?”* Two categories were "No, I do not have any suggestion","yes, I have a suggestion".

There were two students who did not give any suggestions. One student was from Pr1 and the other was from Pr2. The other responds from the category of "Yes, I have a suggestion" differ from each other. One student from Pr1 suggested giving more information about technical background of nanotechnology. One student from Pr2 suggested giving advertisements about NNW and making more people to hear about it. Similar suggestion came from student of Pu2. It was recommended to conduct many more workshops in other schools to inform more people about nanotechnology. The same student also added that since attending NNW, he admired nanotechnology. One student from Pu2 suggested including more daily life examples. The other student from Pu2 recommended adding more presentations to NNW.

5. DISCUSSION AND CONCLUSION

The current research study was designed and conducted to investigate 11th grade students' awareness and conceptual understanding of nanoscience and nanotechnology through a nanoscience and nanotechnology workshop (NNW) while introducing such an important emerging area of science to high school students. The NNW was designed and implemented at Bogazici University, Istanbul. This was a mixed-method study, which involved qualitative and quantitative approaches. The quantitative part was planned as pre-experimental design (pre-test and post-test design without a control group) and the qualitative part included the interviews, observations and artifacts. In this study, a sample of 79 students from 11th grade was included. The students were coming from two different private schools and two different classrooms of one public school. The sample included 18 students from the private school 1 (Pr1); 19 students, 6 of which were grade 12, from the private school 2 (Pr2); 17 students from public school 1 (Pu1) and 25 students from public school 2 (Pu2).

This study was as an attempt to introduce nanoscience and nanotechnology education opportunities to students as citizens and also as future scientists. The NNW can be also considered as a helpful entity for teachers to direct their students' attention to an emerging area of science and technology, nanoscience which could also be connected to some important scientific concepts such as surface area to volume ratio, covalent bonding, intermolecular forces, surface tension, the concepts of hydrophilic and hydrophobic surfaces covered in regular chemistry curricula. However, as Greenberg (2009) mentions, finding connections between curricula and nanoscience is not an easy task and these connections are not always apparent for high school teachers. Nanoscience education projects enable successful integration of nanoscience into secondary school classrooms. As it was pointed out that in NanoSense project which is an example of nanoscience education projects with appropriate preparation and guidance, engagement with well-designed activities could help students to conceptualize core principles that explains the particles in nanoscale and improve students' awareness about science by introducing them to emerging ideas of science and recent real-world applications of science (Schank *et al.,* 2010).

As Schank *et al.* (2007) points out that nanoscience education can promote students' scientific literacy and also prepare them for their further studies. On the contrary, Osborne (2007) reveals that being a scientifically literate citizen by covering the basic concepts of science is not enough in the 21st century. In fact, more opportunities to provide advanced science studies are needed. Moreover, Greenberg (2009) states that nanoscience and nanotechnology education and the training of the new generation mean skilled workforce in those areas in near future. The Vision 2023 project, Turkey classified nanotechnology as one of the strategic technology fields. This could be considered as an evidence of a need for nanoscience and nanotechnology education in high school level. Roco (2003a) also argues that nanotechnology education has an effect on the advancement of nanotechnology. Meaningful and relevant experiences in nanoscience and nanotechnology topics should be introduced to high school students so that the number of students who develop an interest in nanoscience as well as think nanoscience related careers for the future will increase (Schank *et al.,* 2010).

In this study, the first hypothesis was "There will be a significant increase in 11th grade students' awareness of nanoscience and nanotechnology after attending the Nanoscience and Nanotechnology Workshop (NNW)". Student awareness before and after attending the NNW was evaluated through the NNAQ. The 5 point Likert-type Nanoscience & Nanotechnology Awareness Questionnaire (NNAQ) was composed of one part with 20 items.

In order to see the effect of the NNW on students' awareness of nanoscience and nanotechnology, different comparisons between the participating groups were done. Before testing the hypothesis, the participant students were compared with respect to their initial awareness of nanoscience and nanotechnology. Since no significant difference between the students was found, all students were considered as one single group, and the pre-NNAQ and post-NNAQ scores were compared. The whole sample was used to evaluate the NNW's effect on students' awareness of nanoscience and nanotechnology. In the second comparison, public and private schools were compared with respect to their pre-NNAQ and post-NNAQ scores. Two classes from the public high school were compared with the two classes from the private schools to evaluate if there were any differences between public and private schools. In the third comparison, four classes were compared separately to evaluate the effect of the NNW on students' awareness of nanoscience and nanotechnology in different classes. The analysis results of the hypothesis 1 are based on these three comparisons ended up with different conclusions.

First of all, before the instruction, both public and private school student groups demonstrated similar level of awareness about nanoscience and nanotechnology. It was found that both groups had similar level of prior awareness about nanoscience and nanotechnology. One way ANOVA test results showed that there was no significant (<.05) level effect of school background on pre-test scores of NNAQ for the conditions. Based on this result, all the classes were considered as one large sample for the first comparison. This was an expected outcome when students' prior learning about nanoscience and nanotechnology was considered based on the current science curriculum. The interview questions related to awareness of nanoscience and nanotechnology also showed that results were in line with NNAQ. It was found that 13% of students had prior awareness of nanoscience and nanotechnology but could not remember where they heard the two terms. It was revealed that 87% of students were aware of nanoscience and nanotechnology concepts from the media such as the Internet and the news as well as some nanotechnology products such as sport products like clothes. This was also consistent with some previous studies, which have aimed to highlight where most students learned the term "nano". Studies on public awareness of nanotechnology showed that pointed mass media is currently a key factor influencing public awareness about nanotechnology. The study of Waldron *et al.* (2006) showed that most individuals surveyed had heard about nanotechnology from popular press. This finding has been consistent with the current study. In that study, 1500 individuals were surveyed in which teens (aged between 14-17) comprise 5% of the sample and it was found that about 40% of respondents across the age grade of 14-17 were familiar with the term *nano*.

As NNAQ-pre test scores of student groups did not significantly (p>.05) differ from each other, all participants were also considered as one group. The effect of workshop on the *students' awareness* was analyzed by paired sample t-test to compare NNAQ-pre and NNAQ-post scores. There were 20 items and the total score of the test was 100. As alpha (2-tailed) value showed, NNAQ-pre and NNAQ-post scores on NNAQ differed significantly (p=.000). The descriptive study results also showed that the mean of the scores had an increase in the NNAQ-post scores of participants; it was found to be M=83.6456 as the NNAQ-pre scores of participants was M=40.2658. These results revealed that, attending workshop had increased the awareness of students in terms of nanoscience and nanotechnology. This result was consistent with the results obtained from the previous studies, which also aimed to increase the awareness of nanoscience and nanotechnology through specific workshops (Akaygün, 2010a, b; Schank *et al.,* 2010). The results and the conclusions of the evaluation of Nanosense project reported that students made significant gains in understanding of nano-related concepts, (Schank *et al.,* 2010).

The results obtained from the second comparison of the Hypothesis 1 revealed that when private schools were compared with public schools in terms of their NNAQ-pre and NNAQ-post scores, the mean of the scores showed an increase in the NNAQ-post scores of both private and public schools; they were found to be M=81.0541 for the private schools and M=85.9286 for the public schools. Moreover, the mean of score of the private schools in the NNAQ-pre-was M=40.9459 and the mean of score or that of the public schools was M= 39.6667. In order to determine whether there was a significant change in both private and public schools paired samples t-test was used between private and public schools. Paired samples t-test was conducted for private schools and a significant difference in the scores for NNAQ-pre (M=40.95, SD= 12.636) and NNAQ-post tests (M=81.05, SD=11.597) for public schools; t (36) = -15,543, p= .000 was found. Paired samples t-test conducted for public schools revealed that there was a significant difference in the scores for NNAQ-pre (M=39.67, SD= 13.359) and NNAQ-post tests (M=85.93, SD=8.764) of public schools; t(41) = -21,375, p= .000 . In order to determine whether there was a significant difference between the NNAQ-pre mean scores of private and public schools, independent samples t-test was used. As a result of the independent sample t-test analysis, pre-NNAQ mean scores of private and public schools showed no significant difference (p>.05). Similar to that, NNAQ-pre mean scores of private and public schools showed no significant difference. The analysis of NNAQ-pre and post mean scores of each student group were also calculated by nonparametric tests. Nonparametric tests were used since the sample size per each school was small. These results were summarized and concluded as school difference in terms of private and public did not create any significant difference between either NNAQ-pre or NNAQ-post test results. All in all, the analysis of the hypothesis 1 revealed that there was a significant increase in 11th grade students' awareness of nanoscience and nanotechnology after attending Nanoscience and Nanotechnology Workshop (NNW). In other words, NNW was effective in promoting both private and public students' awareness in the aspect of scientific concepts such as nanoscience and nanotechnology. Studies comparing nanoscience and nanotechnology awareness of private and public high school students could not have been found from the literature. However, there were some studies conducted to examine public awareness of nanoscience and nanotechnology (Cobb and Macoubrie, 2004; Scheufele and Lewenstein, 2005; Burri and Bellucci, 2008; Waldron *et al.,* 2006). Lu's study (2009) mainly focused on undergraduate students' awareness regarding to nanoscience and nanotechnology.

In order to test the second hypothesis, different sample groups were formed for data analysis, which was similar to the sample groups used in the data analysis of the NNAQ. To analyze the effect of workshop on conceptual understanding of all participants' both descriptive statistics and paired sample t-test were applied. Descriptive statistics was carried out in order to compare the students' mean scores in the Questionnaire of Conceptual Understanding of Nanoscience and Nanotechnology given before (NNCUQ-pre) and after (NNCUQ-post) the workshop. The mean of score of the students in the NNAQ-pre was M=13.56 and the standard deviation for that scores was SD= 6.057. The mean of the scores showed an increase in the NNAQ-post scores of participants; the mean and the standard deviation for those were found to be M=22.73and SD= 7.216, respectively. In order to determine whether the difference between the NNCUQ-pre and NNCUQ-post mean scores was significant or not, paired samples t-test was used. As a result of the analysis, the difference between NNCUQ-pre scores (M=13.56. SD=6.057) and NNCUQ-post test scores (M=22.73and SD=7.216) of students were found to be statistically different (p=.000), t (78) = -11.796, p=0.000. It was concluded that both descriptive statistics and paired samples t-test showed that NNCUQ-pre and NNCUQ-post scores of all students improved after attending the NNW. As it was analyzed for hypothesis 1, descriptive statistics and independent samples t-test were carried out in order to compare private school students' and public school students' mean scores of NNCUQ-pre and NNCUQ-post. It was found that, the mean of NNCUQ-pre scores showed a significant increase for both private (p=.000), and public schools (p=.000) after attending NNW. The mean of NNCUQ-pre scores for the private schools was M=16.16 and that of the public schools was M=11.26. The standard deviation of scores of the private schools in the

NNCUQ- was SD= 6.067 and that of the public schools was SD= 5.095. The total score of the NNCUQ-pre and NNCUQ-post test were 43. The mean of the scores showed a significant (p=.000) increase in the NNCUQ-post test scores for both private and public schools; and they were found to be M=25.65 for the private schools, and M=20.17 for the public schools. The standard deviation of NNCUQ-post scores were SD= 7.436 and SD=6,008. NNCUQ-pre and NNCUQ-post scores of each private and public schools were compared with nonparametric sign test and descriptive statistics were obtained for students' pre and post test scores in NNCUQ.

For data analysis in this part, nonparametric sign test was used to determine if there was a significant difference between NNCUQ-pre and NNCUQ-post test scores. The reason for nonparametric sign test being used was the small sample size in each group. The number of participants from Pr1, Pr2, Pu1 and Pu2 were 18, 19, 17, and 25 respectively. When the NNCUQ -post test mean scores were compared, it was found that NNCUQ-post mean scores for Pr1 was higher than the mean scores of other groups. It could be suggested that, this difference might be due to the readiness level of this group to the workshop based on the observations of the researcher about this group. It was observed that, the mentor teachers who took Pr1 to the workshop showed their interest to attend this workshop and it may also have a positive effect on students to actively participate to the workshop and took more benefits compare to others. After attending the workshop, the Pr1 also mentioned about the workshop in their school newspaper and they made a short presentation at their school about what they had learned in NNW. On the contrary, NNCUQ-post mean score of Pu1 was found lower than the other groups' mean scores although, there was not a statistically significant difference between the post test scores of the groups. The reason for observing lower mean score of Pu1 in NNCUQ-post may be due to missing data. In other words, the number of students from Pu1 who did not response to NNCUQ–post test was high in number so that, it resulted with a low NNCUQ-post means score.

The results support the hypothesis 2 because a significant increase in conceptual understanding of nanoscience and nanotechnology of 11th grade students who attended Nanoscience and Nanotechnology Workshop (NNW) was found. Overall, the findings showed that the workshop increased students' conceptual understanding of some nanoscience and nanotechnology related concepts. This was evidenced by the significant

NNCUQ-pre to NNCUQ–post test gains. Nonetheless, students' responses in NNCUQ-post and in post interview questions showed that students still had difficulties with scientifically describing nano-related concepts such as nanoparticles, carbon nanotube, buckyballs, STM and AFM. Based on the results, it appeared that students had difficulty in understanding of why properties of a substance differ in nanoscale. Add to this, students also had difficulty to understand the scientific background of nanotechnology applications. This was clearly seen in students' responses that were given in the post interview question number 4. The question was *"Which nanorelated concepts challenged you?-Nanobilim ile ilgili hangi konuları anlamakta zorlandın?"* The frequency distribution showed 62% of students stated that they had some difficulties in understanding. Two of the students from Pr1 stated that they had difficulty in understanding of scientific mechanisms of nanotechnology applications and nanotechnology products. Another student from Pr2 declared that he had difficulty to understand the mechanisms of the microscopes introduced during the workshop, such as electron microscope, STM and AFM. One student from Pu1 mentioned that it was difficult to visualize how small nano is. Therefore, these findings were consistent with the findings of Schank *et al.* (2010) where NanoSense Project including four different nanoscience related curriculum units were developed, pilot-tested and revised. These units were suggested that nanoscience related concepts need to be inserted to the whole or in part of the high school chemistry curriculum. In the final year of the project, evaluation of the curriculum was conducted based on implementations in six different high school classrooms. Short tests including 4-8 questions were developed to assess students' knowledge of concepts covered in the NanoSense units. A six question survey which was adapted from the study of Siegel and Ranney (2003) was implemented to assess the changes in students' attitudes. The goal of the evaluation was to investigate whether the curriculum accomplished its purpose or not. First, students' understanding about nano-related concepts and the nano-related concepts that challenged them were evaluated. The results of the study showed that by NanoSence project implementations, students' understanding of some nano related concepts increased. However, a need for improvement was also mentioned. It was found out that students were challenged by understanding nano-related concepts and the scientific background of their applications. It was also revealed that students' perceptions changed in terms of seeing usefulness of science in daily lives.

The analysis of the research question three examined whether Nanoscience and Nanotechnology Workshop (NNW) includes various outcomes obtained from students or not. The analysis was done for five different outcomes. First one was, analysis of the open-ended question in NNCUQ (the second question); second one was the analysis of group discussion of benefits and risks of nanoscience and nanotechnology; the third one was the analysis of nano product design poster; the fourth one was the evaluation of NNW and the last one was the interviews done before and after the workshop.

The analysis of the open-ended question in NNCUQ which sought for answer to students' awareness of any nanotechnology applications showed that the students' answers for the second question of NNCUQ could have been categorized into seven categories which were nanotechnology products, textile products only, military/defense, health, hi-tech products, ethical/political/socio-economical issues, more than one category answer and no answer. The frequencies and percentages of the pre and post test answers were found for each school. The frequencies of response categories for the second question showed that the answers in the categories of "nanotechnology products" and "textile products" were more than the others. The other category which was remembered mostly was the "hi-tech products". The percentage of the response of "textile products" category answer's percentage was 9 % in NNCUQ-pre test and the percentage was increased to 41 % in the post test. The increase in the percentage of answers for this category could have happened both due to the presentations and the activities of the workshop included the example of "nanotechnology textile products". To investigate possible differences among the students' NNCUQ-pre and NNCUQ-post answers for the second question, first the categories were formed and then chi-square analysis was conducted. "No answers" were taken as missing data. As the expected value in any category was found to be less than 5, the Chi-Square could not be run for testing with these categories. Therefore, for these cases the categories were merged under two categories; *individual benefits* and *global benefits*. Individual benefits included sub- categories of various nanotechnology products, textile and hi-tech products. Global benefits had sub-categories of "military / defense / health / ethical / political / socio-economical issues". Answers that fit into more than one category were classed under new categories according to number of response types. Students' responses showed that frequency of answers given from the category of "Individual benefits" were higher than the frequency of answers given from the other categories. It was consistent with the frequencies of prior categories since individual benefits included sub-categories of various nanotechnology products, textile and hi-tech products. These were the popular answer categories. The answers for both initial and merged categories revealed that "global benefits" category that included "military / defense", "health" and "ethical / political / socio-economical issues" was not represented at a higher frequency. This result could have been because of lack of integration of examples discussed in the NNW related to this category. On the other hand, it could be summarized that, students showed more tendency to give examples which were mentioned in the workshop. The number of responses given for the second question in NNCUQ-pre was 31, and then it increased to 47 in NNCUQ-post. Chi-square test was run for the number of responses given in the second question of NNCUQ-pre and NNCUQ-post. The test statistic was no statistically significant: χ^2 (1. N=78) =0.39. p=.532. Therefore, it could be concluded that there were no statistically significant difference in the number of NNCUQ-pre and NNCUQ-post answers for the second question. This could have been due to missing data in NNCUQ-post. Students might not have wanted to fill in the NNCUQ-post instruments.

As a second outcome, group discussion activity on "Risks and Benefits of Nanoscience and Nanotechnology" was analyzed. The activity was implemented in two different ways. To compare the effectiveness of these two different implementations of the same discussion activity; the first implementation done with Pr1 was repeated by Pu1, the second implementation done with Pr2 was repeated by Pu2.

In the first implementation done with Pr1, an introduction presentation that included some examples of benefits and risks were shared with students to give them some idea before group discussions. After the presentation, each group was asked to discuss the risks and benefits of nanoscience and nanotechnology as a group. It was followed by sharing ideas with other groups. The implementation revealed that, students discussed only the benefits and risks shown in the presentation. Their answers were limited by the content of the presentation. Although, group mentors tried to encourage them to come up with new ideas, students had difficulty to think of other examples of benefits and risks of nanotechnology. Based on this observation, it was decided to revise the implementation and compare its effectiveness with the first implementation. The second implementation with Pr2 started with forming new discussion groups. This time, whole class separated into two big groups. The idea was that, sharing ideas with other members of workshop may enrich the benefits and risks examples. One group was assigned to list risks of nanotechnology; the other group was assigned to list benefits of nanotechnology. When the group works completed, groups discussed benefits and risks, shared their opinions and made a list of benefits and risks of nanotechnology. This discussion part was followed by a short conclusion presentation that summarizes some of risks and benefits of nanotechnology. The products of the activity showed that, students' answers varied compared to the implementation groups of Pr1 and Pu1. Since only the Pr2 and Pu2 schools were asked to list the benefits and risks on a poster, the frequency table included the answers obtained from these two groups. It can be concluded that, the second implementation was more effective when compared to the first implementation in terms of various examples of benefits and risks given by students. For example, the common categories from the discussion presentation and the students' discussion responses were "nanotechnology products", "health", "hi-tech products", "ethical / political / social / economical issues". Students' responses also included "hi-tech products" and "textile products" category. These categories were only mentioned in the introduction presentation of NNW. It can be concluded that, students could remember the examples given in the previous parts of NNW and built discussions on the benefits and risks of these examples. The products of the second implementation also showed that, students gave some examples for each category which were not mentioned during the presentations at the NNW. Some examples from nanotechnology product category were *"fön daha kalıcı olur- Straight hair will be more permanent", "hergün yıkamaya gerek olmayan saçlar-* women *do not have to wash hair every day if nanotechnology is applied", "tadı bitmeyen sakız- chewing gum with non-ending taste"*; from the category of textile products an example was "*su geçirmez kıyafet-waterproof cloth* ", from the category of health, some examples were "*yaşlanmayı geciktirir-prevents aging", "kırışıklıkları önler-prevents wrinkles"*; from the category of military and defense, one example was "*görünmez tank-invisible tank*", from the category of hi-tech products, one example was "*moleküler bilgisayarlar ortaya çıkar-molecular computers will be used"*, from the category of "ethical / political / socio-economical" issues, some examples were "*Turizm gelişir-development of tourism", "günlük hayatta kolaylık sağlar-ease daily life" ,"zamandan, yoldan enerjiden tasarruf-energy efficient in terms of time and distance", "geri dönüşüm bakımından çevre kirliliği azalır-interms of recycling it reduces environmental pollution"*. These examples for each category pointed out a common idea that, students' beliefs about nanotechnology was "to make life easier" with its products. The examples of nanotechnology products also revealed that nanotechnology was considered as a solution for daily life problems related to health, economy, energy and environment. The results of the analysis of interviews revealed that the categories about benefits were found to be "health", "textile products" and "ethical / political / socio-economical issues". The percentage of respondents stated their beliefs about benefits of nanoscience and nanotechnology was 75%, whereas 67% of them gave answers related to "health" category. Ho *et al.* (2011) identified seven items to measure perceived benefits of nanotechnology. Some of these items showed a similarity to the categories formed in this study. The common items were "Nanotechnology may lead to new and better ways to threat and detect human diseases", "Nanotechnology may lead to new and better ways to clean up the environment", "Nanotechnology may help use to develop increased security and defense capabilities", "Nanotechnology may lead to the technologies that will help solve our energy problems", "Nanotechnology may revolutionize the computer industry". There were two more items in the study of Ho *et al.* (2011) that were not included in the current study. The items were "Nanotechnology may give scientists the ability to improve human physical and mental abilities" and "Nanotechnology may lead to a new economical boom" The similar category items obtained from these researches and the current research that might reveal that there were some common benefits of nanotechnology perceptions in general.

Similar to the new answer categories of the second question of NNCUQ, for Pr2 and Pu2, initial categories of benefits were merged into two categories; "individual benefits" and "global benefits". "Textile products" were merged into "individual benefits" category; "military/defense" and "health". "Ethical / social / political / socio-economical issues merged into global benefits category. The frequency of these answers also suggested that the frequencies of answers coming from global category were the highest for both Pr2. However, for Pu2, frequencies of individual category were the highest. However, the number of examples coming from Pr2 and Pu2 differed. The total number of answers coming from both individual and global categories was 52 for Pu2 although the total number was 14 for Pr2. It can be concluded that Pu2 students were more engaged in the discussion activity than Pr2 students were. On the contrary, the workshop evaluation results did not support this conclusion. Addition to this, 49 % of students from Pr2 stated that group discussions were one of the most fun part of the workshop. This was 13 % for Pu2. Then, this difference may be due to the group dynamics during the discussion of benefits and risks. Secondly, it should be noted that group discussions took parts during other activities too.

Similar to the analysis done for benefits categories of nanotechnology, the risk categories were formed and their answer frequencies were calculated. The analysis resulted that similar to the benefits category frequencies, the highest frequency was for "ethical/political/socio-economical" issues category. Other than the categories of benefits, examples from category of nanotechnology products did not include the risks. It can be interpreted as nanotechnology products were not considered as a risk factor by the participating students. Only their benefits were taken into account by students. Again, some examples which were not mentioned in the presentations of NNW were given by students. About the risks of nanotechnology, the examples from "military / defense" category were about wars and weapons. Some of the examples were "*soğuk savaş -cold war*", "*savaşlara neden olabilir –may cause wars*", "*silahlar ve yol açtığı iç ve dış savaşlar-weapons and cause of internal and external wars*", "*yeni geliştirilecek kimyasal, biyolojik silahlar daha çok insanın ölmesine sebep olur- invention of new chemical and biological weapons will cause more people to die*". From the category of health; risks for human health was mentioned with the examples of "*Alerjik –Allergic*", "*nano parçacıklar çok küçük olduğu için vücudumuza çok kolaylıkla girebilir - nano-particles are very small, so they may easily diffuse to the body*". Regardless of students' answers, in the discussion presentation, examples to health issues of other species than human being were emphasized. One example was "*Bucky ball balıklarda büyük beyin hasarlarına yol açabilmektedir- Bucky balls can cause brain damage in fish*" (American Chemical Society, 2004). In the hi-tech category, from Pr2 no examples were stated. From Pu2, there was only one example from this category. It can also be interpreted as, the benefits of nanotechnology on "hi-tech products" were considered more compared to its risks. The examples of benefits for the "hi-tech product" category from Pu2 explain this situation. The examples were "*Moleküler bilgisayarlar ortaya çıkar- Molecular computers will be used*", "*küçük boyutlardaki belleklerde çok fazla datalarımız saklarız - small-sized memory to store too much data*", "*bazı frekanslarda görünmez olma olayı güzel - it is good to be invisible at some frequencies*", "*zamandan kazanır işlerimizi daha kolay yaparız -*

saves time, makes it easier to make work done", "*daha küçük maddeler hakkında bilgi edinmemizi sağlar -helps us learn more about small sized particles".*

As the highest frequency belongs to this category of "ethical / political / socio-economical" issues category, the examples given from these category varies accordingly. The examples related to the ethical issues were "*gizli hayatı riske atıyor -secret life in risk*", "*özel hayata tecavüz -no private life*". Examples of social issues were "insanlar *aylak aylak dolaşır –laziness", "hırsızlık artar-the increase in number of theft".* About the political issues, the examples given were mainly about wars and the relationships between countries. Two examples from Pu2 were *"devletle arası ilişkilere zarar verebilir ve hiç beklenmedik anda savaşlar açılabilir-damage the relations between the state and unexpected wars"*, "*devletler bunu kötüye kullanıp sivil insanların ölmesine sebep olabilir-misuse of nanotechnology by the states may cause deaths of many civilian people*". About the environmental issues, there was only one example given by Pu2 which was "*çevre kirliliği -environmental pollution*". The interview results also revealed that 88% of the respondents stated that their beliefs about risks of nanoscience and nanotechnology; the answers were from the category of "military and defense". Only 14% of students responded from the category of "health". The answers in the category were in line with the category items found in the study of Ho *et al.* (2011), where risk items were "Nanotechnology may lead to the loss of personal privacy because of tiny devices", "Nanotechnology may lead to an arms race between countries", "Nanotechnology may lead to new human health problems", "Nanotechnology may be used by terrorists against the country", "Because of nanotechnology we may lose jobs", "Nanotechnology may lead to more pollution and contamination". Different from the current research, one more item was found in the study of Ho *et al.* (2011). That item was "uncontrollable spread of very tiny self-replicating robots". In that study, researcher aimed to compare public and scientific experts' differences in their perceptions of risks and benefits about nanotechnology in the US. They measured the items with experts samples on a 5- point scale ranging from 1=*strongly disagree* to 5=*strongly agree*. For the public sample, 10-point scales ranging from 1= do not agree at all, to 10= agree very much was used in the measurement. The same items were also used in the study of Cacciatore *et al*. (2011). They examined risks and benefits perceptions interacting with specific associations in shaping attitudes toward nanotechnology. The similar category items were obtained from these researches and the current research might reveal that there were some common risks of nanotechnology perceptions in general. The common risk perceptions were about the category of “military / defense”, “health” and “ethical / political / socio-economical” issues. From the category of “military /defense, some of the common examples were “nanotechnology might lead to arms race between countries”, “unexpected wars”, “misuse of nanotechnology might cause death of civilian people”. From the category of “health”, some common examples were “nano particles may diffuse to the body”, “damages skin”. From the category of “ethical / political / socio-economical” issues, the common examples were “private life in risk”, “loss of jobs”, “environmental pollution”.

Cacciatore *et al.* (2011) stated that the perceptions of risks and benefits might influence people’s attitudes differently when nanotechnology was associated with issues like human health and issues related to medical field. Similar to that, when people associated nanotechnology with leisure activities, they could associate- it with sports equipments. Based on this, Cacciatore *et al.* (2011) hypothesized that mental associations of people would affect the perceptions of benefits and risks on support and usefulness of nanotechnology. The authors also suggested that the importance of associations with machines and computers were also led to more technophile respondents to associate nanotechnology to machines and computers and likely to have more positive attitudes to nanoscience and nanotechnology.

At the end of the workshop, in order to evaluate the NNW, students’ feedback about the NNW was taken by administering Nanoscience and Nanotechnology Workshop Evaluation Questionnaire (NNWEQ). Ten open-ended questions were asked to get detailed information.

The answers collected from each participant were coded accordingly to the question numbers. Based on these categories, a frequency table showing the percentages of answer categories obtained from each school was formed. The analysis of this frequency table showed that “the most informative part of the workshop” was selected as presentations that were followed by activities and experiments. None of the students suggested any non-informative part of the NNW. They either said “no, not exist” or they did not respond to this question. The answers for “the most impressive part of the workshop” were “use of nanotechnology areas", "benefits and risks" and "nano textile and water activity". These answer categories were also consistent with the answer categories taken from the interviews. "The most fun part of the workshop" stated as the activity parts including nano textile and water test, product design, hydrophilic and hydrophobic activity and group discussions. This result indicated that, students enjoyed hands-on activity parts where they actively involved in learning more than the other activity parts. The frequency of the answer of "the most boring part of the workshop" question also supported this result since presentation part indicated as most boring part with the filling in papers including activity papers and the instruments. Similar to that conclusion, the suggestions about "to be avoided part" also showed that, students suggested to omit long presentations and filling out papers during the NNW. However, their suggestion was not about omitting the presentations completely. They also suggested that presentations should stay as part of the NNW within the activities, videos about electron microscope, STM and AFM, product design, contact angle measurement and discussions. Moreover, students indicated that they would have wished to visit a real nanotechnology laboratory and use real electron microscope rather than watching how it works from a video. They also said that they would have liked to see more nanotechnology products and learn more detailed information about how nanotechnology products were produced in laboratories. Students were also asked, "if they would like to attend further workshops that could be implemented about nanotechnology". The percentage of students from each school responded to this question as "yes' were 85% for Pr1; 66% for Pr2, 53% for Pu1 and 80% of Pu2. Students' suggestions about developing and redesigning of the NNW were about adding more visuals and activities, shorter presentations, seeing real electron microscopes, STM and AFM part. Except Pr1, the rest of the three schools, there were students who commented this question with the answer of "it was good and effective".

The answers for the questions were quite expected. As the workshop was about nanotechnology and it took place in a Bogazici University campus, it was normal that students imagined attending a workshop in a real nanotechnology laboratory at the university. Since these expectations of students were taken into account while designing the workshop, in the introduction presentation, it was emphasized that not all universities have a nanotechnology research laboratory. A video was attached to the presentation that showed a real clean room and how the researchers work in that clean room. Also, students were willing to see and use real electron microscope and STM and AFM. Originally, while designing the NNW, it had been planned to have a visit to Bogazici University Advanced Technologies R &D Center where an electron microscope and an AFM was located. However, permission for visits to that center could not be verified since the devices were only in use of researchers from the university and they were fragile. Therefore, conducting a visit to that laboratory with 18 students at least was not an option. For that reason, an interview was conducted with the laboratory assistant. She gave a brief explanation about the use of electron microscope while she examined some examples with electron microscope. The visuals taken from that electron microscope were also shared with students. With another research assistant in that laboratory, AFM device was checked and the functions of the AFM were explained via video record. These videos were edited and attached to the second presentation, which was about the microscopes that are used in nanotechnology.

In the last activity, student groups designed “a nanotechnology product”. Each group of students was asked to come up with a new nano product idea, with a slogan and an explanation of their product. Each group created a poster representing their product design idea. An activity having students design their own nanotechnology products was used to be engaging, focused, and offering many design possibilities. As Kirby (2008) mentioned in such a design project students tried to differentiate their designs from others to gain a sense of individuality. Kirby (2008) also added that this activity helped students to identify new perspectives about design challenges and solutions for the future. In Kirby’s study (2008), students were asked to design a pinhole camera to give high school students an opportunity to design a product, which they did not have the experience of. Although, in the current study students only had an opportunity to create a design idea, it shared similar perspectives with the study of Kirby (2008) in terms of trying to help students to use their potentials to create new ideas and to gain different perspectives.

After the group poster design activity, each poster was analyzed and the product ideas were placed in the categories that were used in the second question of NNCQ and group discussion results. The reason for categorizing the product design ideas was to see if there would be any similarity or difference between the design ideas and benefits and risks perceptions of nanotechnology. The categories that most of design ideas for all groups took in a place were “nanotechnology products”, “health”. The category of “Textile products” was only observed in Pr1 and Pu2. “Military and defense” was observed in all groups except Pr2. “Hi-tech product” category was observed in Pr2, Pu1 and Pu2. No products took place in the category of “ethical / political / socio-economical issues”.

The results showed that the NNW increased students’ awareness and conceptual understanding of nanoscience and nanotechnology. On the other hand, the post- interview results showed that students had difficulties in scientifically describing nano-related concepts such as nanoparticles, carbon nanotube, buckyballs, STM and AFM. They had difficulty in understanding why properties of a substance differ in nanoscale. Students also mentioned in both post-interviews and NNWEQ that they would like to learn more about the production process of nanotechnology applications. The results also supported that students’ benefits and risks perceptions showed similarities to the studies of Cacciatore *et al.* (2011) and Ho *et al.* (2011).

5.1. Limitations of the Study

The limitations of the study related to the sample were the sample size and the types of schools. The sample size was 79 students (Pr1= 18, Pr2= 19, Pu1= 17, Pu2 = 25). There were three different schools; two of them were private schools and the other was one public school. Students from two different classes of the public school attended the NNW. Because of the small sample size and convenient sampling, the results of the study cannot be generalized to all grade 11 students in Turkey. In other words, the findings of the study were valid for this sample and similar ones.

Since the workshop was planned to be held during a weekday at Bogazici University, schools had to plan this activity as an extra-curricular activity and followed the same procedure of a field trip including the arrangement of service buses and getting parents’ permission. These procedures required time and extra work for teachers. Moreover, most of the schools plan their field trips at the beginning of the year and integrate them into the yearly plan. Attending such activities during the year may cause difficulty when making arrangements.

The other limitation was about arranging activity place and time. Although the activity was supposed to take place at the secondary school science teaching laboratories at Bogazici University, the laboratories were not available on the weekends. Therefore, the NNW had to be planned on a weekday.

Another limitation was timing. Since schools were invited to Bogazici University, their arrival and return time were limited to a regular school day's schedule. That is, they had about six hours to complete the NNW. As the NNW was engaging with various activities, presentations and paper fill-out forms, students were asked to give short breaks during the day. As the school groups did not have a flexible time for the NNW, students had difficulty to fill in the post instrument papers. This led to the loss of data for the analysis. Another reason behind data loss was that students were not willing to fill in the forms. The NNWEQ results indicated that filling in the forms was the boring part of the NNW.

Another limitation was not being able to visit the research center. Although there was a research center, Bogazici University Advanced Technologies R & D Center, that includes an electron microscope and and AFM, no permission could be taken to have a visit. It would be better for students to see a real electron microscope in a research laboratory of the university. Also, there was not a contact angle measurement device.

A follow-up activity could not be done effectively for the following reasons. One reason was that students were searched on Facebook according to their names. However, they could not be easily found since there were many research results that showed the same name. Although students were told that they could also find the BU NANO group on Facebook and be a member of it, no one joined the group by themselves. One teacher suggested that when BU NANO name was searched on the Internet, the group name did not appear. Therefore, Facebook group did not function as expected.

The mentors played an essential role in the NNW. Without their voluntary participation, the implementation of the NNW could not be done. This group of mentors participated in Akaygün's (2010a,b) study, which was about the design and implementation of a nanotechnology workshop for pre-service teachers. They took active role in the nanotechnology workshop, which took place in the ILKYAR organizations in 2010 and 2011. In that organization, schoolteachers were the participants of the workshop. Although the mentors had experiences in another nanotechnology workshop, they took active part during the planning and design of the NNW. They attended regular meetings.

5.2. Recommendations for Further Research and Implications

In this study, a visit to Bogazici University Advanced Technologies R&D Center was planned in the design process of the NNW. However, permission for a visit could not be taken. Therefore, the visit had to be cancelled. The researcher had an interview with the researcher, who was responsible from the use of scanning electron microscope and other devices such as AFM, in the R&D center. The researcher intended to video record the interview as well as the electron microscope and AFM. However, the quality of the recording was poor. This could have a negative effect on the students' understanding of the tools used in nanotechnology. In further studies, it will be to the researchers' advantage to have permission to visit the R&D center with students. This will enable students to have experience with tools such as electron microscopes. Video recording and editing can be done professionally. Long presentations in the workshop can be avoided. The number of hands-on activities can be increased. As for the NNEWQ and the post interview results, more detailed information about the production process of the nanotechnology applications should be added to the NNW. According to the NNWEQ results, it is recommended to integrate hands-on activities, especially the 'Solving the Mystery of Lotus Effect', 'Nano Product Design Activity' and the second implementation of the 'Benefits and Risks of Nanoscience and Nanotechnology Discussion Activity' to the further implementations.

For further studies, the NNW can be planned for two days instead of one day. Invitations to schools can be sent out at the beginning of the year and schools can easily integrate the NNW into their yearly plan. Implementation of nanotechnology education in schools is an opportunity to increase student awareness of nanotechnology as an emerging field of science (Greenberg, 2009). To reach more students in Turkey, the NNW could be redesigned as a nanotechnology teaching kit and it could be offered to schools. Teachers could integrate the activities in that kit into their curriculum. Within the interdisciplinary aspect of nanotechnology, teachers may also make connections between chemistry, physics and biology lessons. A nanotechnology course can be offered to high school students. Collaborative partnerships between high schools and universities should be developed. Universities should give opportunities to high school students to experience nanotechnology education in laboratory environment with hands-on activities.

APPENDIX A: NANOSCIENCE AND NANOTECHNOLOGY AWARENESS QUESTIONNAIRE (NNAQ)

Değerli Katılımcı,

Katılımcısı olduğunuz bu anket, sizin nanoteknolojiye ilişkin farkındalıklarınızı belirlemek amacıyla hazırlanmıştır.
Çalışmanın diğer bir amacı ise anket sonuçları ışığında okul dışı nanoteknoloji eğitimi ile ilgili hazırlanan bir atölye çalışmasını geliştirmektir. Gönüllü olarak katılmanızı umduğumuz bu ankette, nanoteknoloji ile ilgili maddeler bulunmaktadır.

Maddelere içtenlikle, en uygun bulduğunuz cevabı vermenizi umuyoruz.

Maddeler hakkında yapacağınız derecelendirmeler sadece bilimsel amaçlı kullanılacak olup kesinlikle sizi yargılama amaçlı değildir.

Anket öncesinde sizden isteden kişisel bilgileriniz de başkaları ile paylaşılmayacak, gizlilik hakkınız korunacaktır. Gizliliğin sağlanabilmesi, ön test ve son test uygulamalarının eşlenebilmesi için ankete, size açıklandığı şekliyle bir kod yazmanız istenecektir.

Yapacağınız derecelendirmelerle ile çalışmaya katkı sağlayacağınız için şimdiden teşekkür ederim.

Saygılarımla,

Berra Sagun
Ortaöğretim Fen ve Matematik
Alanları Eğitimi Master Öğrencisi

Kod #:

Okulunuz: **Cinsiyetiniz: K / E**
Sınıfınız: **Doğum Tarihiniz: __ / __ / _____**
Not Ortalamanız:

Bu anketin amacı **nanoteknoloji** hakkındaki farkındalığınızı belirlemektir. Aşağıda 20 adet önerme verilmiştir. Her önermeyi okuyunuz. Her bir önerme ilgili görüşünüzü **1'den 5'e size uygun olan numarayı yuvarlak içine alarak belirtiniz.**
(**1(katılmıyorum)** ile **5 (tamamen katılıyorum)** olacak şekilde).

	Katılmıyorum				Tamamen katılıyorum
1. Nanoteknoloji terimini tanımlayabilirim.	1	2	3	4	5
2. Dergi, gazete, kitap, internet vb. kaynaklardan nanoteknoloji hakkında bir şeyler okudum.	1	2	3	4	5
3. Daha önce nanoteknoloji ile ilgili ders, kulüp, seminer, yaz okulu vb. etkinliklere katıldım.	1	2	3	4	5
4. Nanometrenin teknik bir uzunluk ölçü birimi olduğunu biliyorum.	1	2	3	4	5
5. Nanoboyutta bir madde örneği verebilirim.	1	2	3	4	5
6. Nanoteknolojinin hayatımı doğrudan etkileyişine örnek verebilirim.	1	2	3	4	5
7. Nanoparçacık terimini tanımlayabilirim.	1	2	3	4	5
8. Karbon nanotüp hakkında bilgi verebilirim.	1	2	3	4	5
9. Nanoteknolojinin topluma sağladığı faydalara örnek verebilirim.	1	2	3	4	5
10.Nanoboyutta ölçümler yapılmasını sağlayan araçlara örnek verebilirim.	1	2	3	4	5
11.Bucky ball terimi hakkında bilgi verebililirim.	1	2	3	4	5
12.Nanoteknolojinin sunduğu yeni kariyer imkanlarına örnek verebilirim.	1	2	3	4	5
13.Nanoteknolojinin beraberinde getirdiği risklerden birini açıklayabilirim.	1	2	3	4	5
14.Nanoteknoloji alanında yapılan bir uygulamayı söyleyebilirim.	1	2	3	4	5
15.Nanoteknolojinin hangi farklı alanlarda uygulandığını söyleyebilirim.	1	2	3	4	5
16.Nanobilim terimini açıklayabilirim.	1	2	3	4	5
17.Nanoteknoloji ile ilgili araştırmaların yürütüldüğü alanları örneklendirebilirim.	1	2	3	4	5
18.Nanoteknolojinin gelecekte hayatımı nasıl etkileyeceğini açıklayabilirim.	1	2	3	4	5
19.Nanoboyuttaki nesnelerin üretimi için uygulanan süreçleri örneklendirebilirim.	1	2	3	4	5
20. Yeni geliştirilen nanoteknolojik ürünlere örnekler verebilirim.	1	2	3	4	5

APPENDIX B: NANOSCIENCE AND NANOTECHNOLOGY CONCEPTUAL UNDERSTANDING QUESTIONAIRE (NNCUQ)

Kod #:

Kavram Testi

BÖLÜM I. *Nanobilim/ Nanoteknoloji*

1. **Aşağıda verilen terimleri daha önce duydunuz mu? Bu terimler ile ilgili size uygun olan şıkkı işaretleyin. Eğer duyduysanız, kendi cümlelerinizle kısaca açıklayınız.**

- **Nanobilim**
  - a) Duymadım Açıklayamam.
  - b) Duydum ama açıklayamam
  - c) Duydum. Bence

- **Nanoteknoloji**
  - a) Duymadım Açıklayamam.
  - b) Duydum ama açıklayamam.
  - c) Duydum. Bence

- **Nanoparçacıklar**
  - a) Duymadım Açıklayamam.
  - b) Duydum ama açıklayamam.
  - c) Duydum. Bence

- **Karbon nanotüp**
  - a) Duymadım Açıklayamam.
  - b) Duydum ama açıklayamam.
  - c) Duydum. Bence

- **Taramalı Tünel Mikroskobu (Scanning Tunneling Microscope. (STM)) ve veya Atomik Kuvvet Mikroskobu (Atomic Force Microscope.(AFM))**
- Duymadım Açıklayamam.
- Duydum ama açıklayamam.
- Duydum. Bence

2. **Herhangi bir nanoteknoloji uygulaması biliyor musunuz? Biliyorsanız, bu uygulama hangi alanda yapılmış? Örnekler veriniz. Bu uygulamaları nereden duydunuz?**

BÖLÜM II. Boyut

Soru 1, Soru 2 ve Soru 3'ü yukarıda verilen maddelere göre cevaplayınız.

a. İnsan saçının kalınlığı **e. Bacillus bakterisi**

b. Toplu iğne başı **f. Elektron**

c. Su molekülü **g. Oksijen atomu**

d. DNA sarmalının genişliği **h. Virüs**

1. Yukarıda belirtilen maddeleri boyutlarına göre büyükten küçüğe dizebilir misiniz?

> > > > > > >

2. Herbir maddenin tahmini olarak boyutlarının ölçülerini verebilir misiniz? (İpucu: toplu iğne başı 1 mm genişliktedir)

a) İnsan saçının kalınlığı **e) Bacillus bakterisi**

b) Toplu iğne başı **f) Elektron**

c) Su molekülü **g) Oksijen atomu**

d) DNA sarmalının genişliği .... **h) Virüs** ....

3. Yukarıda verilen maddeleri benzer boyutlarına göre gruplandırır mısınız?

4. BÖLÜM III.Kuvvet ve Etkileşimler

1) Su damlası bir zemin üzerinde yuvarlak şekilde duruyor. Bu zeminin özelliği hakkında ne söyleyebilirsiniz?

2) Bir tür kertenkele olan 'gecko' ların kirli bir yüzeyde yürürken ayaklarının kirlenmemesinin sebebi ne olabilir?

3) Bir su örümceği suyun yüzeyinde yürüyerek dolaşabiliyor. Bunun nedenini açıklayabilir misiniz?

APPENDIX C: NANOSCIENCE AND NANOTECHNOLOGY WORKSHOP EVALUATION QUESTIONNAIRE (NNWEQ)

Grup No:

İsim Kod:

NANOBİLİM ATÖLYESİ DEĞERLENDİRME SORULARI

1. **Atölye çalışmasının en bilgilendirici yanı** ____________________

2. **Atölye çalışmasının yeterli detayda bilgilendirici olmadığını düşündüğünüz konu**

3. **Atölye çalışmasından edindiğin en etkileyici bilgi** ____________________

4. **Atölye çalışmasının en eğlenceli konusu** ____________________

5. **Atölye çalışmasının en sıkıcı konusu**

6. **Atölye çalışmasının içeriğinden çıkarılmasını önerdiğin 3 şey**

▪

▪

▪

7. **Atölye çalışmasında mutlaka kalsın dediğin 3 şey:**

▪

▪

▪

8. **Atölye çalışmasında başka olsaydı dediğin 3 şey**

▪

▪

▪

9. **Grup liderim hakkındaki düşüncelerim** ____________________

10. **Proje sorumlusu (Berra Hanım) hakkındaki düşüncelerim**

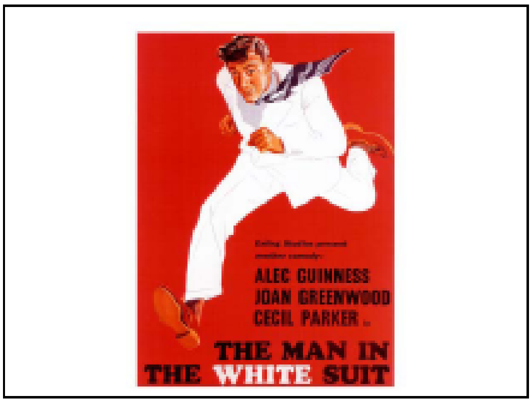
11. **Bu atölye çalışmasından başka nanobilim ve nanoteknoloji ile ilgili başka bir çalışmaya daha katılmak ister miydiniz?**

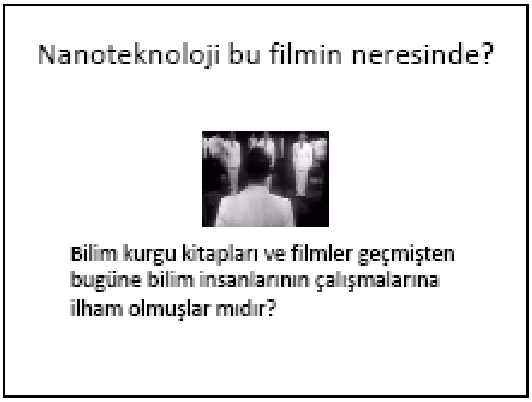
isim: ____________________

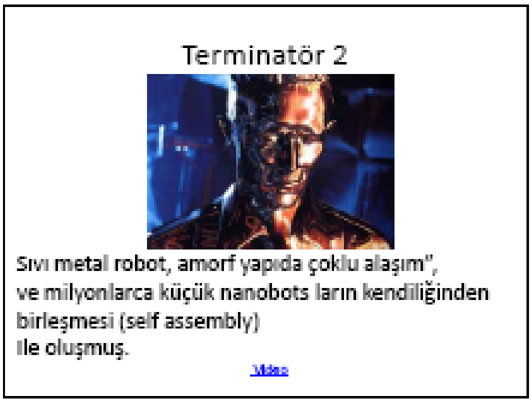
email: ____________________

12. **Bu atölye çalışmasını geliştirmek ve daha etkili kılmak için sizin önerileriniz nelerdir?**

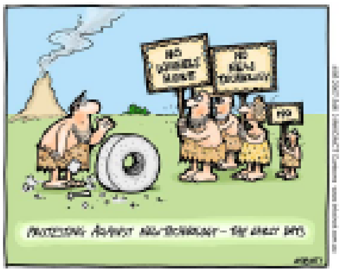
APPENDIX D: THE INTRODUCTORY POWERPOINT PRESENTATION





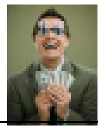


Neden Teknolojik Gelişmeler?



Tüm gözler nanoteknoloji üzerinde peki neden?

- Google arama motorunda nanoteknoloji kelimesi: yaklaşık 9.990.000 sonuç
- 2015 yılı için "Global Nanoteknoloji Piyasası" hacminin 3 trilyon dolar olarak tahmin ediliyor.



Peki Dünya buna hazır mı?

Yeterli bilim insanı var mı?

2015'de 2.5 milyon İnsan İhtiyacı!!!

- Siz de gelecekte nanobilimde yerinizi almak ister misiniz?

Mike Roco, NSF,Nanobilim, Mühendislik,Teknoloj Çalışma Grubu Başkanı,2003

Nanoteknoloji ne o zaman?

<u>Nanoboyutta</u>

- **Ölçme**
- **Kontrol**
- **İşleme**
- **Birleşme(Entegre)**

Daha ayrıntılı bir tanım?

Nanoboyut?

18.Yüzyıl öncesi
Renk değiştiren vazo

- Roma Dönemi

18.Yüzyıl öncesi
Vitray Boyaları

- Ortaçağ

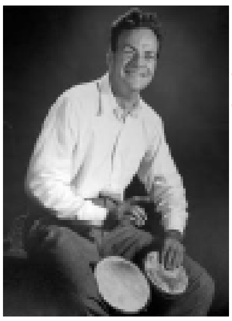
19. Yüzyıl
Fotoğraf
Nanoteknolojinin ilk örneklerinden

- **1827**
- Işığa duyarlı, gümüş nanoparçacıkların oluşması

Louis Daguerre,1839

İlk Nanoteknoloji Fikri

Bongo çalan bu kişiyi tanıdınız mı?



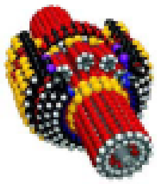
Richard Feyman, **1959**
'Temelde bir çok oda var"
There's Plenty of Room at the Bottom"
'24 ciltlik Britannica Ansiklopedisini
bir toplu iğnenin başı büyüklüğünde bir alana sığdırabiliriz.'

Nanoteknoloji kelimesi ilk defa ne zaman tanımlandı?

- Nario Taniguchi (1974, Tokyo Üniversitesi)
- 1 nm doğruluk ve ultra ince üretim teknolojisi

Nanoteknoloji terimi ilk ne zaman kullanıldı?

- Dr.Eric Drexler (biyolojik sistemlerden esinlenilerek molekül yapılardan makineler yapılabilir.) 1977

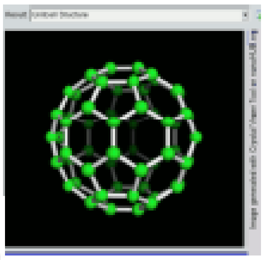


Nano'yu ilk gözlemleyen

- Nanoteknolojinin babası
- Prof.Dr. Heinrich Rohrer
- Taramalı Tünelleme Mikroskobu (STM), 1981
- Nobel Fizik Ödülü

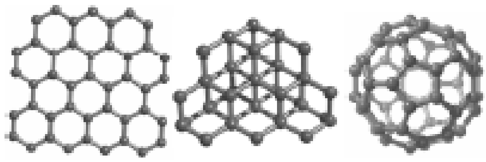
Buckyball (C60)

- 1985
- Fulleren
- Küresel Şekil
- Grafit
- Yüksek dayanıklılık



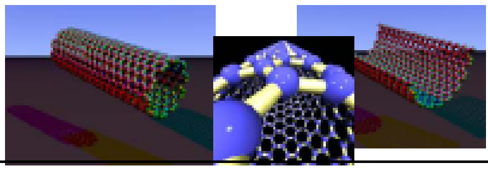
Karbonun Allotropları

Grafit Elmas Buckyball



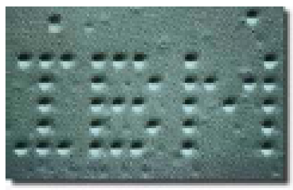
Karbon Nanotüp

- Slindir şeklinde katlanmış grafit
- Çelikten yüz kat daha sağlam
- ve çok esnek
- -190 °C ile 1600 °C dayanıklı



90'larda Nanoteknoloji

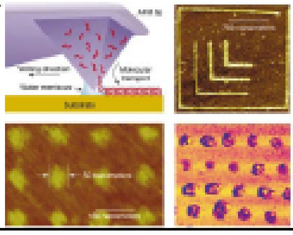
- Atomlara Müdahale



35 Xenon Atomu nikel kristalinin üzerinde

2000'lerde Nanoteknoloji

- Nano Litografi
- Nano boyutta yapılar elde etme; elektronik aletler



Nano

Ön ek

'nanos' Cüce (yunanca)

10^{-9} (1 milyarda bir)

Nanometre (nm)

1m=1000mm=100000 µm=1000000000nm

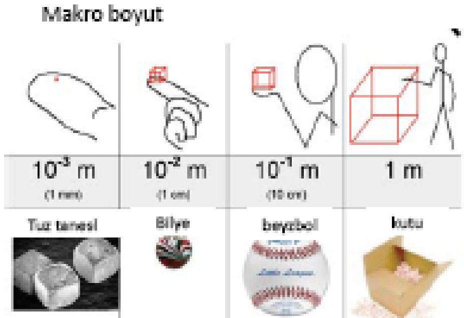
- Metre, metrik sistemin temel uzunluk ölçü birimi
- 1 metre'yi gözümüzde canlandırmak kolay mı?
- 1 metrenin milyarda birini gözümüzde canlandırmak kolay mı?

Nano boyutu anlamak

- PowerofTen

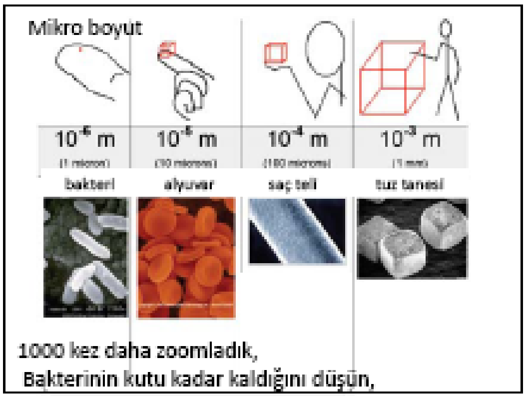
BOYUT AKTİVİTESİ

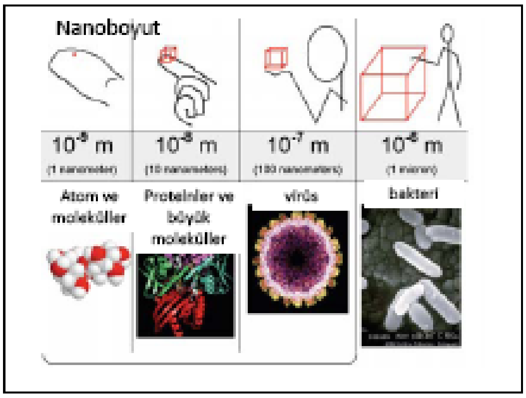
Makro boyut

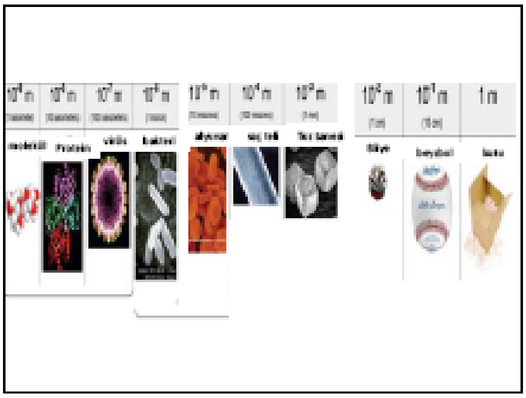


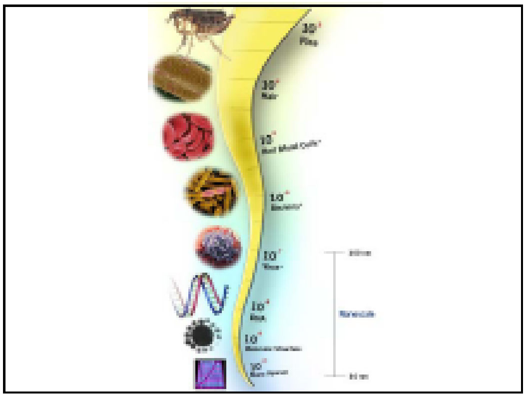
1000 kat daha zoomladığında,

Tuz tanesinin kutu boyutunda olduğunu düşün,

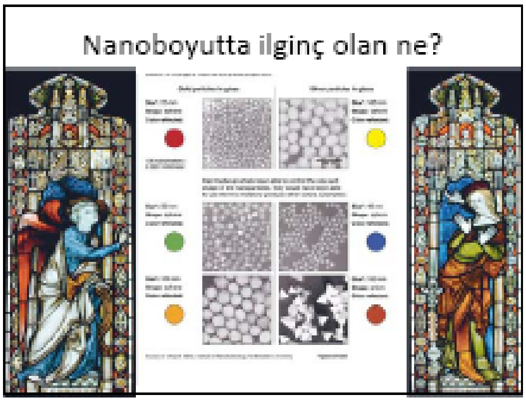

Mikro boyut
10^{-6} m
(1 micron)
bakteri
10^{-5} m
(10 microns)
alyuvar
10^{-4} m
(100 microns)
saç teli
10^{-3} m
(1 mm)
tuz tanesi
1000 kez daha zoomladık,
Bakterinin kutu kadar kaldığını düşün,


Nanoboyut
10^{-9} m
(1 nanometer)
Atom ve moleküller
10^{-8} m
(10 nanometers)
Proteinler ve büyük moleküller
10^{-7} m
(100 nanometers)
virüs
10^{-6} m
(1 micron)
bakteri






Bu vitrayda Altın Çözeltisi ile boyanmış kısım hangisidir?

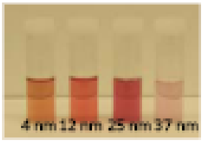

Nanoboyutta ilginç olan ne?

Au Nanotanecikleri

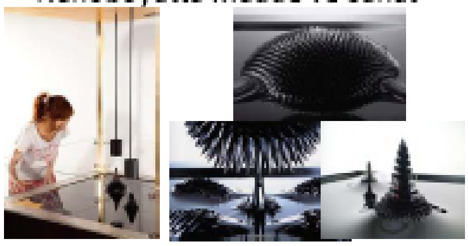
Külçe Altın

Au nanotanecik

Şarap kırmızısı



Nanoboyutta Madde ve Sanat

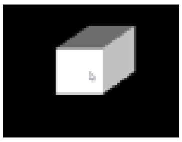


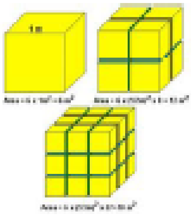
Ferrosıvı Heykelleri, Japon bilim insanı ve sanatçı Sachiko Kodama

videoplayback.flv

Nanoboyutta ilginç olan ne?

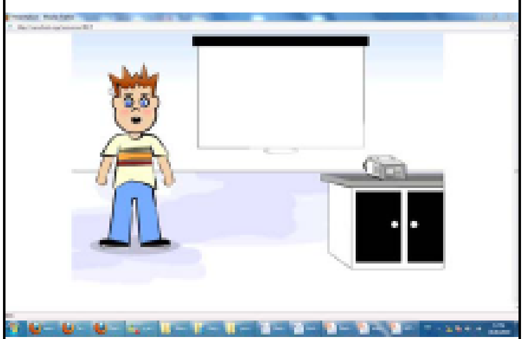
- Yüzey Hacim oranı artar
- Yüzey ile daha çok temas
- Daha iyi katalizörler





Nanoteknoloji

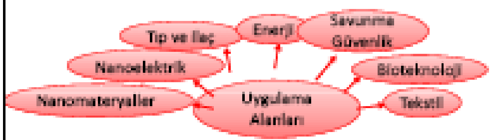
- İki farklı yaklaşım:
- Aşağıdan yukarıya (bottom-up)
- moleküler nanoteknoloji
- ve organik veya inorganik yapıları, maddenin en esas birimi olan atomlardan itibaren atom atom, molekül molekül inşa edilmesi
- Az kullanılır.
- Yukarıdan aşağıya (top-down). Makineler, asitler ve benzeri mekanik ve kimyasal yöntemler kullanılarak nano boyuta getirmek. (Heykel yapmak gibi)



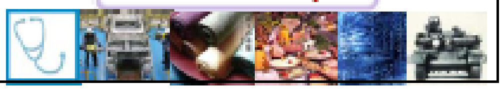
Nanoteknoloji Nasıl bir Ortamda Geliştirilir?

- Temiz oda(clean room)
- http://www.youtube.com/watch?v=NZEOshKrR-g

Nanoteknoloji Uygulama Alanları



Nanoteknoloji



Nanomateryaller

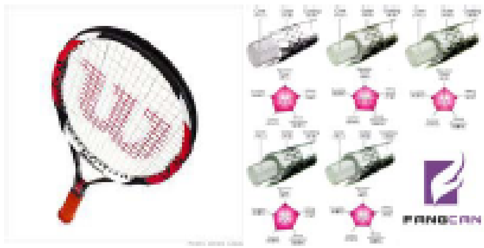
- Karbon nanotüp
- Nano çubuklar
- Buckyball(Fulleren)

OLED

- Işık yayan organik diyot
- Elektrik verildiğinde ışık yayan organik moleküllerden yapılmış ince filmdir.

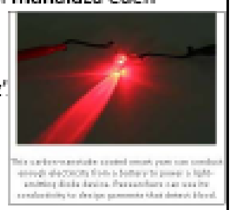
LED,LCD ye göre az enerji
Daha parlak,daha canlı görüntü

http://www.pclabs.com.tr/2008/10/27/oled-nedir-nasil-calisir/

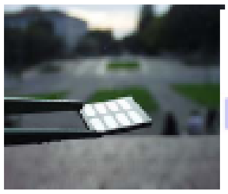


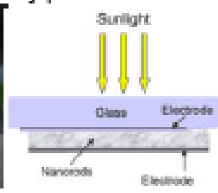
Enerji Muhafaza Eden Kumaşlar

- Karbon nanotüplerden oluşan boya ile boyanan kumaşlar enerjiyi muhafaza eden birer pile dönüştü.
- 'giyilebilir elektronik cihaz'



Nano Güneş pilleri





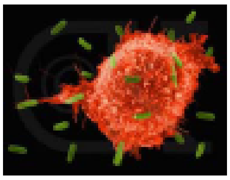
Yarı iletken polimerin içine yerleştirilen Inorganik nano çubuğun, iki elektrodun arasına sıkıştırılması

Sağlık

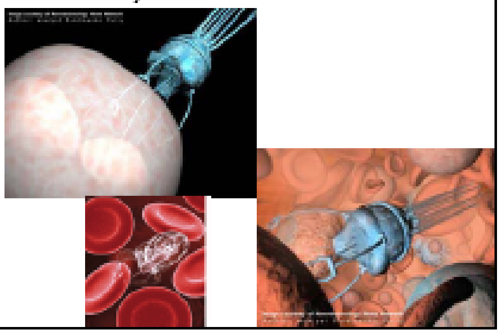
- Nanoparçacıklar,
- Nanorobotlar
- Kuantum noktaları

Anti kanser altın nanoparçacıklar

- Radyasyon uygulandıktan sonra enerjiyi emerek kanser hücresini öldürüyorlar.

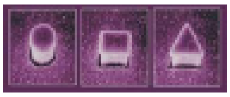


Ameliyatlarda Nanorobotlar



Erken teşhis

- UV ışığında parlayan quantum noktaları
- Bu noktalar UV ışığında serbest elektron içerir ve foton yayar.

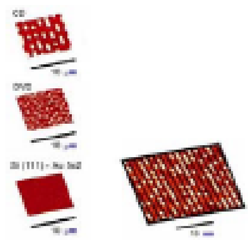


Farede erken tümör teşhisi

Teknoloji

- **Teknoloji**
- Daha iyi data saklayabilmek
- Daha küçük aletler ve çipler üretmek

DVD' nizde 1.000.000 kat daha fazla bilgiyi saklayabilmek ister miydiniz?



Korsan Dvd'nin Sonu

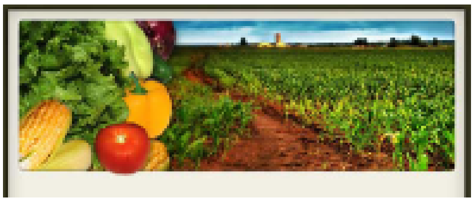
- CD ve DVD'ler, nanoteknoloji tabanlı parmak izine dayalı kripto sistemi ile korunacak. www. nanoteknolojinedir.com, 8.10.09

Gıda sektöründe Nano

Uzun raf ömrü

Nanoparçacıklar vitamin ve minerallerin taşınmasını sağlıyorlar

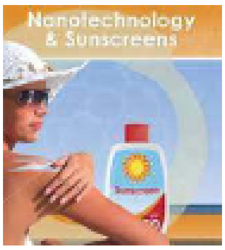
Tarım sektöründe



Mineral Su Tutucuları

Kozmetik Alanında

Nano partiküllü Güneş Kremleri



UVA ve UVB'yi engelleyen titanyum oksit ve çinko oksit

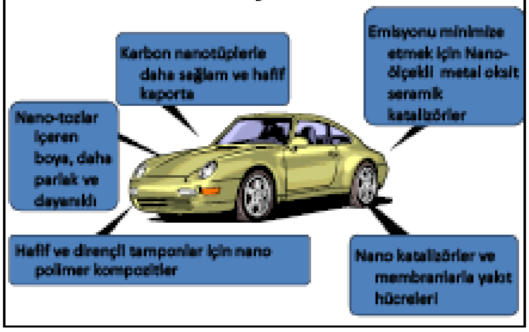
Tekstil Alanında

Dayanıklı nanoboyalar

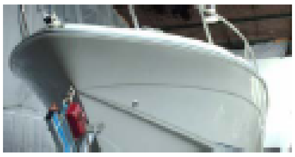
- Kir ve su tutmaz
- Çizilmeye karşı dayanıklı
- Nano tozlar içerenboya ile

daha açık ve parlak renkler

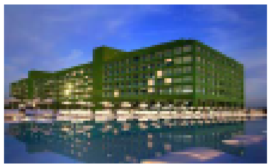
Nanoteknoloji ile Otomotiv



Tekne ve Gemileri Kızağa Çekmeye gerek kalmadı



Nano silgi ile Bina Cephelerini Temizlemek mümkün mü?



Havayı temizleyen nanoboyalar

- Ultraviole ışınına maruz kalan

Boyadaki Titantum dioksit

nano parçaları

organik ve inorganik çevre kirliliğine yol açan maddeleri parçalıyor.

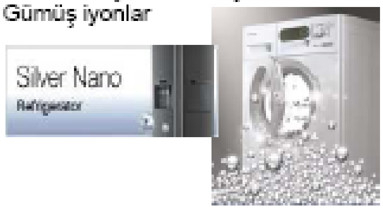
Formaldehit gibi maddeleri

ayrıştırıyor

Suyu Temizleyen Nano Filtreler

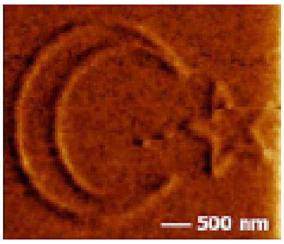
Antibakteriyel Çamaşır Makinesi ve Buzdolabı

Bakteri oluşumuna karşı
Gümüş iyonlar



Türkiye'de Neler Oluyor?

Nanolitografi tekniği ile dünyanın en küçük Türk bayrağını çizmek



Çizgileri
100 nanometre
genişliğinde ve
2 nanometre
yüksekliğinde

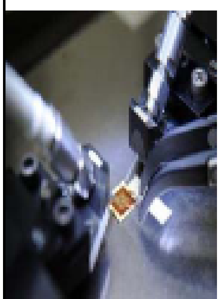
TNT Patlayıcılar Gübreye Dönüştürebilir mi?

Ulusal Nanoteknoloji
Araştırma
Merkezi'nden
(UNAM)

Silinen Parmak İzleri Tespit Edilebilir mi?

Hacettepe Üniversitesi Kimya Bölümü florasan özellikli sprey şeklide ortama sıkılan nanopartiküller parmak izinde bulunan aminoasitler ile etkileşime girer ve florasan özelliği sayesinde parmak izleri kolaylıkla görülebiliyor.
www.cnnturk.com

Radyasyona dayanıklı malzeme

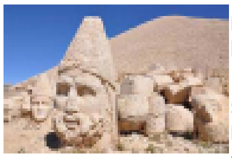


- Uzay projesi (Savunma Sanayi Müsteşarlığı)
- Uyduların elektronik devrelerinin, uzaydaki radyasyona karşı 100 kat dayanıklılığını sağlıyor. TURKSAT 5A da da kullanılacak.
- Uzayda ilk kullanan ülke, Türkiye

Harry Potter'ın Görünmezlik Pelerinine sahip olmak ister misiniz?

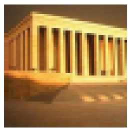
- Cisimler belli frekanslarda görünmez olabiliyor.
- Askeri araç ve uçakların üstü kaplanabiliyor.
- 31.07.09

Tarihi yapıları nanoteknoloji ile koruma altına alabilir miyiz?



Nano tanecikli
kalsiyum hidroksit çözeltileri
ve
silika çözeltileri
Nanoteknoloji ürünü
tekstiller ile koruma

13.12.10



Nanoteknoloji Araştırmaları Üniversiteler

- Gebze Yüksek Teknoloji Enstitüsü
- İTÜ
- ODTÜ
- AÜ
- Fatih Üni

Nanoteknoloji ile ilgili Lisans ve Lisansüstü Bölümler

- Lisans bölümü yok
- Yükseklisans ve doktora
  - Bilkent Üniversitesi,Malzeme Bilimi ve Nanoteknoloji
  - Hacettepe Üniversitesi, Nanoteknoloji ve Nanotıp
  - ODTÜ,mikro ve nanoteknoloji
  - Anadolu Üniversitesi,nanoteknoloji

- 2011'de

Sabancı Üniversitesi
Nanoteknoloji Merkezi açılıyor.

Nanoteknolojinin riskleri var mıdır?

- Nanoparçacıklar vücudumuza solunum ve deri yolu ile girebilirler mi?
- Bazı nanoparçacıklar, yüksek yanıcı özelliğe sahip
- Çevre kirliliği, mevcut filtre sistemlerin etkisiz kalışı
- Gizliliğe saldırı
- Silah
- İşsizlik

Gelecekte Neler Olacak?

Gelecek de bir gün gelecek

- Daha güçlü bilgisayarlar, bilgi depolama birimleri
- Daha hızlı kimyasal analizler
- Tıp, tedavi,tanı ve ilaçlarda yeni yaklaşımlar
- Daha dayanıklı malzemeler
- Enerji üretim ve dönüşümleri için yeni teknolojiler

Gelecek de bir gün gelecek

- Moleküler bilgisayarlar
- Mükemmel bir geri dönüşüm
- Çevre kirlenmesinin önlenmesi, kirlenmiş kaynakların temizlenmesi
- Yaşlanmanın yavaşlatılması
- Yapay bağışıklık sistemi oluşturan nanobot ordular
- Moleküler seviyede hücre tamiri

Gelecek de bir gün gelecek

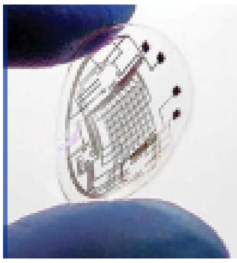
- Asfalt yerine solar yollar ile enerji üretimi
- Moleküler gıda sentezi ile kıtlığı önlemek

Ekonomik, elektronik fonksiyonlar

Gümüş ve altın nanotüp ile kaplanmış plastik
Kağıt esnekliğinde dokunmatik ekranlar

Güneş paneli sensörleri
24.05.10,
http://news.discovery.com

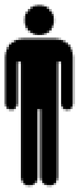
Aynaya baktığınızda kan şekerinizi ölçen lensler

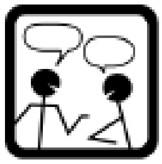


Nanoteknolojik Telefonlar

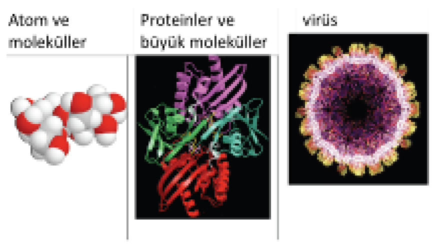
- Nokia Morph
- Fonksiyonuna göre
- şekil ve boyut değiştirebilir.

Atölye Çalışmaları





APPENDIX E: SCALE ACTIVITY



10^{-4} m (100 mikron)	10^{-3} m (1mm)	10^{-2} m (1cm)	10^{-1} m (10 cm)	1m

10^{-9} m (1 nanometre)	10^{-8} m (10 nanometre)	10^{-7} m (100 nanometre)	10^{-6} m (1 mikron)	10^{-5} m (10 mikron)

APPENDIX F: INDIVIDUAL & GROUP ACTIVITY SHEETS

Grup No:
İsim Kod:

Nanoşehir'de Isınma Turları

Yer: Bilim Merkezi
Aktivite İstasyonu I

Makasla Keserek Nano Boyuta Küçültebilir miyiz?

Kesmeden Önce

Bireysel Tahminim:

1. 1 nanometre uzunluğunda bir kağıt elde etmek için kağıdı _____ defa kesmeniz gerekir.

2. Size verilen kağıdı kesmek imkansız olana kadar   kere kesebilirsiniz.

Şimdi grup arkadaşlarınızla birlikte kağıdı ikiye kesmeye başlayabilirsiniz.

Kestikten Sonra

Aktiviteden Çıkardığım Sonuç:

Grup No:
Sözcü İsim kod:

Nanoşehir'de Isınma Turları
Yer: Bilim Merkezi
Aktivite İstasyonu 1

Makasla Keserek Nano Boyuta Küçültebilir miyiz?

Göreviniz: Size verilen kağıdın uzunluk ölçüleri 150 mm x 5 mm. Bu kağıdı, eni aynı kalacak şekilde her defasında iki eşit parçaya kesin. Yaklaşık 1 nm uzunluğa ulaşana kadar kesmeniz isteniyor

Not:Görevinizi tamamlamak için hesap makinesi, cetvelden de yararlanabilirsiniz.

Kesmeden Önce:

! Grup çalışmanıza başlamadan önce, bireysel tahmin kağıtlarınızı doldurmalısınız. Sonra, kağıdı ikiye kesmeye başlayabilirsiniz.

Hatırlatma: Kaç defa kestiğinizi ve elde ettiğiniz kağıt uzunluklarını milimetre ve nanometre cinsinden verilen tabloya not etmeyi unutmayınız.

Kestikten Sonra

Grup Cevaplarınız:

1. **Kağıdı keserek imkansız olana kadar kaç kere kesebildiniz?**
2. **Keserek elde ettiğiniz en küçük kağıt parçası kaç nanometredir?**
3. **Sizce makas nanoboyuta ulaşmak için kullanışlı oldu mu? Açıklayınız.**
4. **Kağıdı elde ettiğiniz en küçük kağıt parçasından da küçük boyutlara kesmeniz mümkün mü? Cevabınız evet ise, sizin öneriniz nedir?**
5. **1 nm uzunluğunda bir kağıt elde etmek için kağıdı kaç defa kesmeniz gerekir?**

! Grup sonucunuzu yazmadan önce, bireysel sonuç kağıtlarınızı doldurmalısınız.

Aktiviteden Çıkardığınız Sonuç:

Grup :

Kağıt Kesme Sayısı 0	Kesilen Kağıt Uzunluğu (milimetre) 150 mm	Kesilen Kağıt Uzunluğu (nanometre) 150 000 000 nm

Grup No:
İsim Kod:

Nanoşehir'de Keşfe Devam..
Yer: Bilim Merkezi
Aktivite İstasyonu 2

Nanoboyutta Nasıl Görüyoruz?

Görev1
Görevden Önce:

Bireysel Tahminim:

1. Optik mikroskopla göremeyeceğimiz kadar küçük boyuttaki maddeleri nasıl incelersiniz? Göremediğimiz bir nesnenin şeklini ve boyutunu nasıl bilebiliriz?

Şimdi grup arkadaşlarınızla birlikte kum aktivitesine başlayabilirsiniz.

Aktiviteden Çıkardığınız Sonuç:

Bireysel :

Grup No:
Sözcü isim kod:

Nanoşehir'de Keşfe Devam…

Yer: Bilim Merkezi
Aktivite İstasyonu 2

Nanoboyutu Nasıl Görüyoruz?

Görev1

Göreviniz: Elinize bir kalın çubuk, bir şiş, ucu pamuk kaplı çubuk alarak, elinizdeki kutuların içine sırayla sokun. Malzemelerin ucuyla kutunun tabanını yavaşça tarayarak inceleyin. Sizce kutunun tabanında ne var? Tahmininizi şekil çizerek gösterin.

(Lütfen sadece size verilen çubuklar ile inceleme yapın).

		Kutunun Tabanında ne var?
Kutu 1	Kalın çubuk ile inceleme	
	Pamuk uçlu çubuk ile inceleme	
	Şiş ile inceleme	

Görevden sonra:

Grup Cevaplarınız:

1. Kutunun tabanı hakkında nasıl bir bilgiye ulaştınız?

2. Hangi çubuk, kutunun taban yüzeyini daha ayrıntılı olarak incelemenize yardımcı oldu?

3. Çubukla kutuların tabanındaki nesneyi incelerken fazla kuvvet uygulasaydınız ne olurdu?

Görev 2: Kapalı kutunun içindekinin boyutunu bulalım

Göreviniz: Elinize bir iğne alıp, kutunun yüzeyine batırarak kutunun <u>içindeki nesnenin şekli ve boyutunu tahmin etmeye çalışın</u>.

Grup Cevabınız:

1. **Kutunun içindeki nesnenin şekli nedir?**

2. **Kutunun içindeki nesnenin boyutlarını iğne ve cetvel yardımı ile bulun.**

Videoyu izledikten sonra aşağıdaki soruları cevaplayınız.

Grup Cevaplarınız:

3. **Sizce görev 1'deki kutu ve çubuklar neyi temsil ediyor?**

4. **Sizce görev 2'deki iğne ve kutu neyi temsil ediyor?**

! Grup sonucunuzu yazmadan önce, bireysel sonuç kağıtlarınızı doldurmalısınız.

Aktivitelerden Çıkardığınız Sonuç:

Grup :

Grup No:
İsim Kod:

Nanoşehir'de Isınma Turları
Yer: Üretim Merkezi
Aktivite istasyonu 3

Görevden Önce

Bireysel Tahmininiz:

1) Lotus yaprağı (nilüfer yaprağı) yüzeyinde su taneciklerinin yuvarlak şekilde durabilmesinin sebebi ne olabilir?

2) Sizce leke tutmayan, su geçirmeyen yüzeyler nasıl elde ediliyor?

**Şimdi grup arkadaşlarınızla birlikte su geçirmezlik, leke testlerine başlayabilirsiniz.**

Aktiviteden Çıkardığım Sonuç:

Grup No:
Sözcü isim kod:

Nanoşehir'de Tanıma Turları
Yer: Üretim Merkezi
Aktivite istasyonu 3

Bu aktivite istasyonunda sizi 2 farklı görev bekliyor.
Görev1: Su Geçirmezlik testi   Görev2: Kendini Temizleme Testi

Görev1:Su testi

Su testini 2 farklı yaprak ve 4 farklı kumaş üzerinde yapacaksınız.

1. **Her bir yaprağın üzerine sırasıyla pipet ile bir damla su damlatın.** Ne gözlemlediniz? Damlaları karşılaştırın. Bir fark görebiliyor musunuz? Evet ise bu fark nedir?

	Su damlası yaprak üzerinde nasıl görünüyor?Şekli nasıl? Fark var mı?
Yaprak 1(açık yeşil)	
Yaprak 2(koyu yeşil)	

Grup Cevaplarınız:

- Su damlacığının yaprak üzerinde aldığı şekil sizce neye veya nelere bağlı?
- Su damlacığının üzerine parmağınızla bastırın. Su damlasının şekli değişti mi? Sizce neden?

2. **Size verilen 4 farklı kumaşın üzerine sırası ile su damlatın.** Damlaları karşılaştırın. Bir fark görebiliyor musunuz? Evet ise bu fark nedir?

	Su geçirdi mi? (Evet/Hayır) **Su damlasının şekli nasıl?**
Pamuklu Kumaş	
Sentetik Kumaş	
Nano Kumaş	
Nano Kaplama Kumaş	

Grup Cevaplarınız:

- **Yapraklar ve farklı kumaşlar üzerinde duran su damlaları ile ilgili yaptığınız gözlemler arasında benzerlik var mı ? Açıklayınız.**

- **Sizce her su geçirmeyen kumaş nano kumaş mı?**

Sunumu izledikten sonra Görev 2'ye geçiniz.

Görev2: Kendini Temizleme Testi

1. **Şimdi de hidrofobik yüzeye sahip olan yaprağın ve nano kumaşınız üzerine çok az miktarda toprak koyun. Tekrar pipetiniz ile kirlenmiş yaprak ve nano kumaş yüzeyine birkaç damla su damlatın. Yaprağı yavaşça su damlasını yüzeyde hareket ettirecek şekilde eğin. Ne gözlemlediniz? toprak parçacıklarına ne oldu? Çizerek gösteriniz.**

	Su damlası ve toprak parçacıkları ile ilgili ne gözlemlediniz? Lotus etkisi'ni gözlemleyebildiniz mi?
Yaprak(Hidrofilik yüzeyli)	
Nano kumaş	

Sunumu izledikten sonra :

Grup sonucunuzu yazmadan önce bireysel sonuç kağıtlarınızı doldurmalısınız.

Aktiviteden çıkardığınız sonuç:
Grup:

Grup İsim:
İsim Kod:

NanoŞehir' de Tartışıyoruz

Nanoşehir Fikir Paylaşım Platformu

Aktivite istasyonu 4

Tartışma Konusu: Nanoteknolojinin Risk ve Faydaları

Tartışmadan Önce:

Bireysel Tahminim:

1) Sizce nanobilim ve nanoteknoloji hangi riskleri beraberinde getiriyor?

2) Sizce nanobilim ve nanoteknoloji hangi yararları beraberinde getiriyor?

Şimdi nanobilim ve nanoteknolojinin riskleri ve yararları ile ilgili grup tartışmasını yapabilirsiniz.

Aktiviteden Çıkardığım Sonuç:

Grup İsim:
Sözcü İsim kod:

NanoŞehir' de Tartışıyoruz

Nanoşehir Fikir Paylaşım Platformu

Aktivite İstasyonu 4

Bireysel tahminlerinizden sonra grup tartışmasına başlayabilirsiniz.

Tartışma Dosyası:

Nanoteknolojinin Getirdiği Riskler ve Faydalar

<u>Grup Tartışması</u>

1) Sizden istenen nanoteknoloji hakkında öğrendiklerinizi düşünerek, bu teknolojinin yaygınlaşmasını fayda ve risk yönünden grup arkadaşlarınız ile tartışmanız.

(İp ucu: **Toplumda yer alan farklı insanları göz önüne alarak, tartışmanızı yapın.** *Üretici , Tüketici , Çevre Bilimleri , Tarım ve Balıkçılık gibi* alanları göz önünde bulundurun. **Tartışmalarınızda; çevre, sağlık, güvenlik, ekonomi, etik gibi alanları düşünebilirsiniz).**

Faydalar:____

____

____

Riskler:____

____

____

Fikirlerinizi diğer gruplar ile de paylaşın.

Sunumu izledikten sonra tartışmadan çıkardığınız grup sonucunuzu yazın.

Tartışmadan Çıkardığınız Sonuç:

Grup :

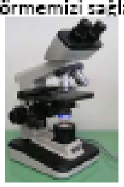
APPENDIX G: PRESENTATION: "TOOLS IN NANOTECHNOLOGY"

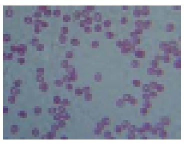
Nanoteknoloji Araçları

- Araçlar değiştikçe,görebildiklerimiz ve yapabildiklerimiz de değişiyor

Görmek

- Çıplak gözle yaklaşık 20 mikron'a kadar görebiliyoruz.
- Optik mikroskop yaklaşık 1 mikronu görmemizi sağlar.



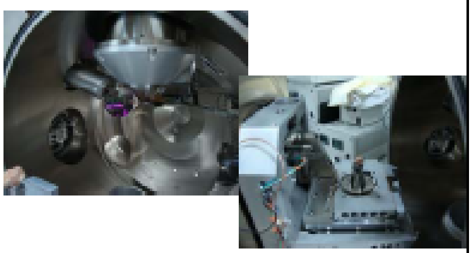


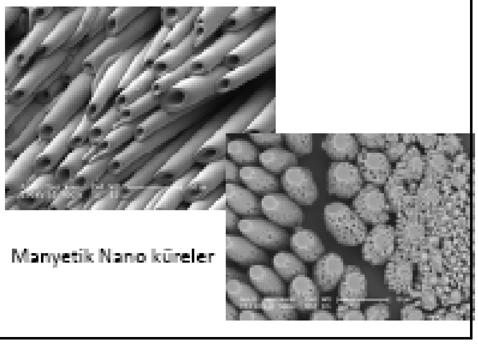
Görmek

- Çıplak gözle
- Optik mikroskopla
  - Sperm hücresi
  - Kan hücresi
  - Amip
  - Paramesyum

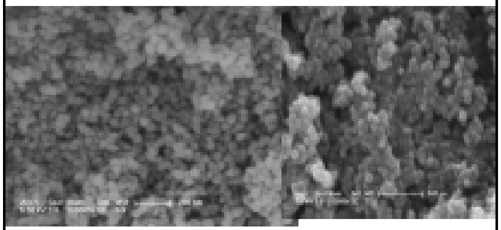
- Optik Mikroskop ile göremeyeceğimiz kadar küçük boyuttaki bir nesneyi nasıl inceleriz?
- Şeklini nasıl bilebiliriz?

Elektron Demeti ile Malzemeyi İncelemek

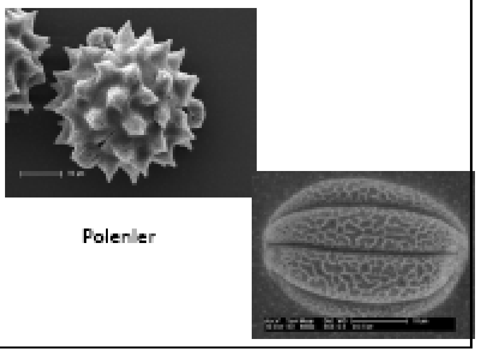




Manyetik Nano küreler



Silisyum Nano parçacıklar

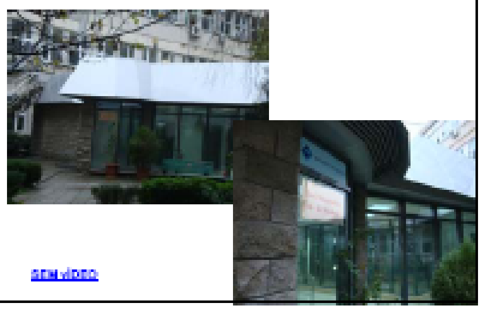


Polenler

Micro organizma

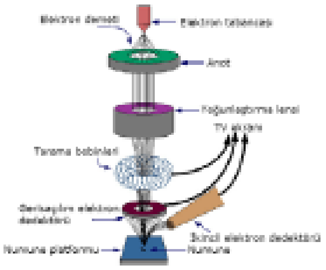
Elektron Mikroskobu(SEM)
1935

Boğaziçi Üniversitesi ArGe Merkezi



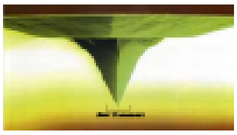
SEM VİDEO

MIKROSKOP KOLONU



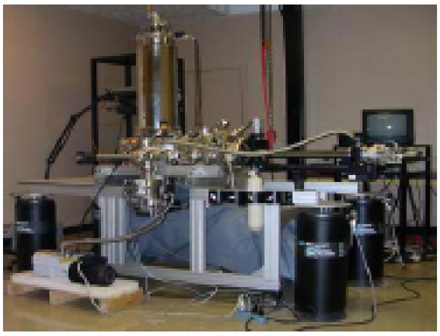
Yüzeye Dokunmak

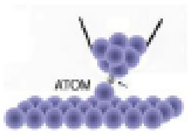
- Taramalı Uç Mikroskobu
  (Scanning Probe Microscope)

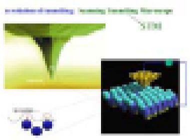


Taramalı Uç Mikroskobu

- Taramalı Tünelleme Mikroskobu Scanning Tunneling Mikroscope (STM)
- Atomik Kuvvet Mikroskobu (AFM)







STM'in Kullanım Alanları

- Atomları manipüle etmek için(yerlerini değiştirmek için)
- Metallerin yüzeylerini 3 boyutlu görüntülemek için
- Yüzeylerin pürüzlülüğünü ölçmek için

Video

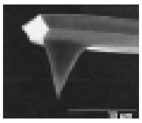
- http://www.dailymotion.com/video/xz7dx_nanotechnologie-stm_tech

Atomik Kuvvet Mikroskobu (AFM)

- Nano boyuttaki olayları, yüzeyleri görüntülemek ve anlamak
- Yüzeydeki kuvvetleri ölçmek

Atomik Kuvvet Mikroskobu (AFM)

- Yüzeyden iğnenin ucuna (silisyum veya silisyum nitrat) etki eden elektromanyetik kuvvet.
- iğnenin ucu aşağı ve yukarı hareket eder.



Video

- http://www.azonano.com/nanotechnology-video-details.asp?VidID=101

Boğaziçi Üniversitesi ArGe Bölümü AFM cihazı

AFM Cihaz Video

Nanoşehir Bilim Merkezi

Nanoboyutta Nasıl Görüyoruz?

Görev1: Kutunun Tabanında Ne var?

- Kutunun tabanı hakkında nasıl bilgi elde ettik?

Tarama yöntemi

- Hangi çubuk daha ayrıntılı bilgi etmemizi sağladı? Şiş
- Fazla kuvvet uygulasaydık?
  - Taban yüzeyi bozulabilirdi.
  - Çubuk zarar görebilirdi.

Görev2: Kapalı Kutunun içindekinin boyutunu nedir?

- Kapalı kutu resmi
- Içindeki nesnenin resmi
- Boyutu:

Aktivite Sonuçları

- Görev1:
  - Kutu: İncelenen yüzey
  - Çubuklar: STM Uç
- Görev2:
  - Kutu: İncelenen yüzey
  - İğne: AFM Uç

APPENDIX H: PRESENTATION: "LOTUS EFFECT & ITS APPLICATIONS"

Nanoşehir Üretim Merkezi
Aktivite 3

Su Geçirgenlik Testi
Kendini Temizleyebilme Testi

Görev 1: Su Testi

	Su damlası yüzeyde yayıldı mı? Şekli nasıl?
Yaprak 1 (açık renk)	Hayır / Yuvarlak
Yaprak 2 (koyu renk)	Evet
Pamuklu Kumaş	Evet
Sentetik Kumaş	Hayır/Yuvarlak
Nano Kumaş	Hayır/Yuvarlak
Kaplanmış Kumaş	Hayır/Yuvarlak

- Su damlasının bazı yüzeylerde yuvarlak şekilde kalması nasıl açıklanabilir?

Hidrofobik/Hidrofilik Yüzeyler

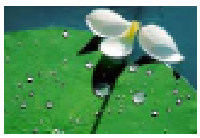
- Hidrofobik yüzey???
- Hidrofilik yüzey???

Hidrofobik/Hidrofilik Yüzeyler

- Hidrofobik yüzey: 'hydro' 'phobos'
- sudan korkan, suyu sevmeyen
- Hidrofilik: 'hydro' ' philia'
- Suyu seven

Doğadan Hidrofobik Yüzeylere Bir Örnek: Lotus Yaprağı

Video

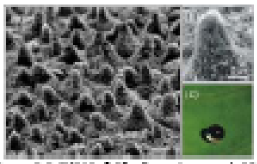


Doğada Gözlem

- Almanya,1975
- Barthlott, Wilhelm, Christoph Neinhuis

'lotus yaprağı yüzeyi ince bir kütikula (kütin+mum) ile kaplı'.

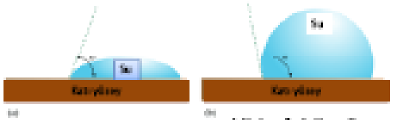
Hidrofobik Yapı Su Damlasının Yuvarlaklığını Nasıl Sağlar?



Yüzey pürüzlülüğü: 5-10 mikrometre çapında küçük tepecikler
&
Hidrofobik yüzey: 1nm çapındaki hidrofobik tabaka

Kütikula kaplı yüzey tabakası, yüzeyle su arasında hava sıkışmasını sağlar, aradaki etkileşimi düşürür.
su damlası üzerine düştüğünde yüzey tarafından itilir, yuvarlak şekil alır.

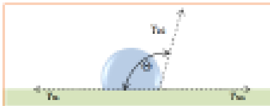
Temas Açısı & Hidrofobik/ Hidrofilik Yüzeyler



Hidrofilik yüzey   Hidrofobik yüzey

Temas Açısı (Contact Angle)

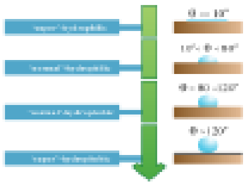
- Temas açısı



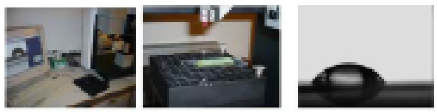
Etkileyen faktörler:
- Yüzey enerjisi (yüzey gerilimi sonucu)
- Yüzey Pürüzlülüğü

Temas Açısı & Hidrofobik/ Hidrofilik

- Yüzeyler, temas açısına göre sınıflandırılabilirler.



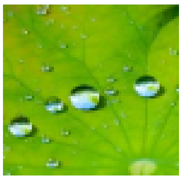
Temas Açısı Nasıl Ölçülür?



re 2. A contact angle goniometer with digital measurement capabilities. (Images credit: MMRO, Aal
versity, Creative Commons Attribution ShareAlike 3.0)

Lotus Etkisi (1)

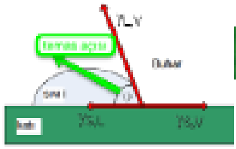
Süperhidrofobik Özellik



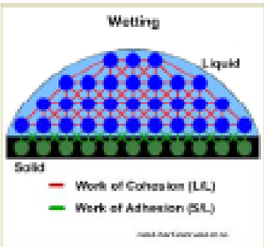
Lotus Efektin Dayandığı Temel Prensip

- Katı yüzey üzerindeki sıvıya etki eden kuvvet.

Bu kuvvetler nelerdir?



Katı ve sıvı faz arasındaki (γS,L), katı ve buhar fazı arasındaki (γS,V) ve sıvı ile buhar fazı arasındaki (γL,V) kuvvetler tüm yüzey gerilimini tanımlamaktadır

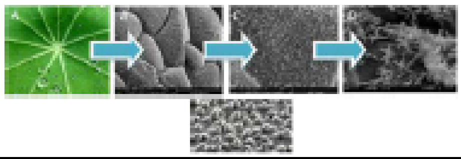


Başka Bitkilerde de Hidrofobik Yapı Görülür mü?

Çimen, Aslan pençesi, latin çiçeği, gingko,lahana,akasya...

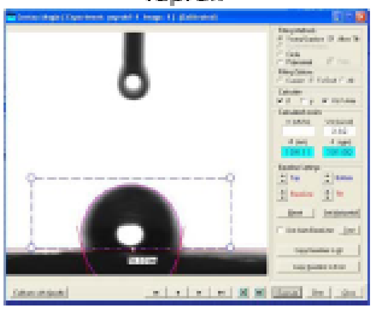
Ortak özellik:

Mikro ve nano boyutta yüzey pürüzlülüğü

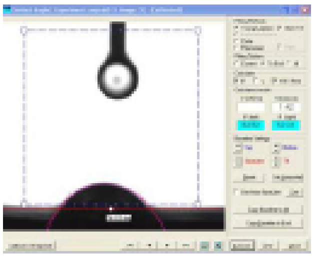


Başka Bitkilerde de Hidrofobik Yapı Görülür mü?

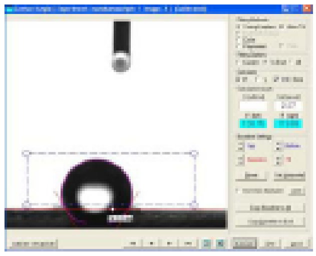
Yaprak



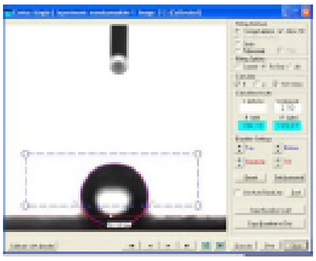
Yaprak 2



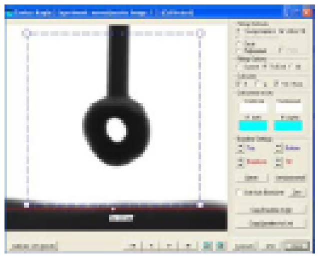
Nanokumaş



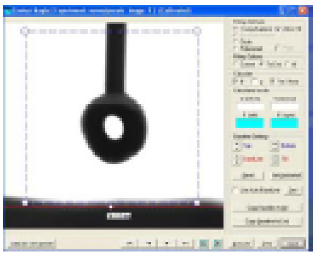
Nano kumaş 2



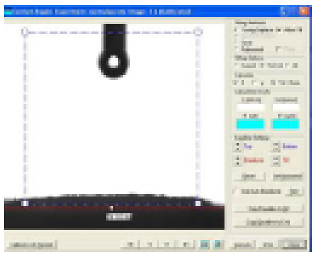
Normal peçete



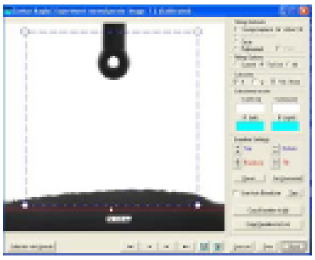
Normal peçete 2



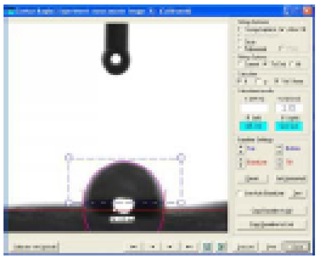
Normal peçete 3



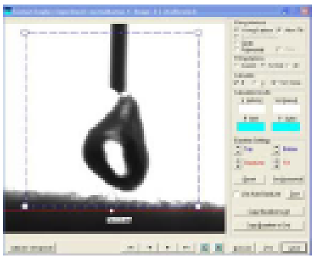
Normal peçete 4



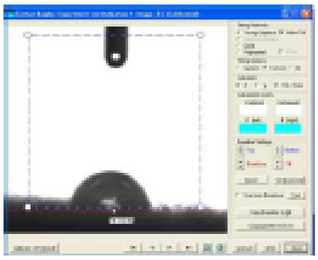
Nano peçete 5



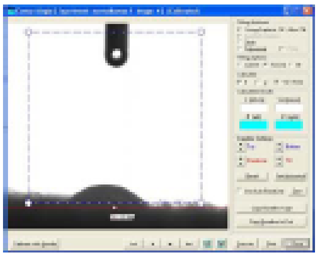
Normal Kumaş



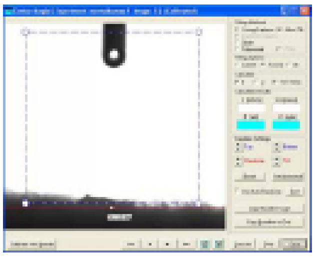
Normal Kumaş 2



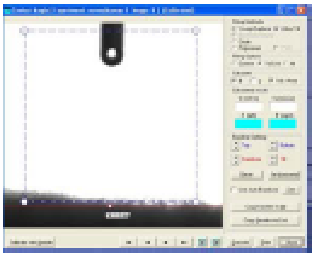
Normal Kumaş 3



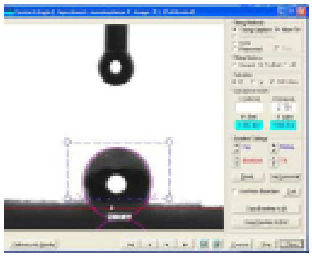
Normal Kumaş 4



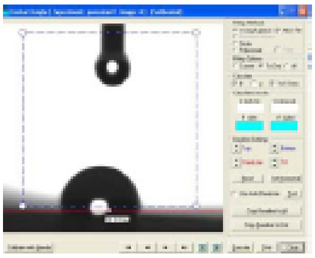
Normal Kumaş 5



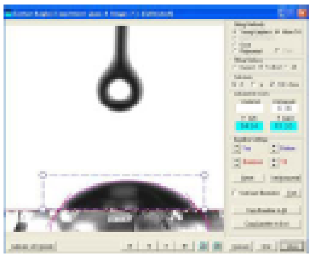
Kaplama kumaş



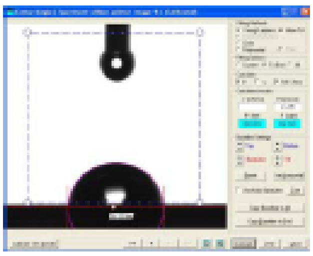
Ponza Taşı



Normal Cam

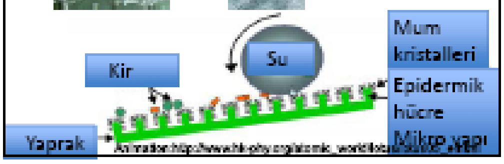


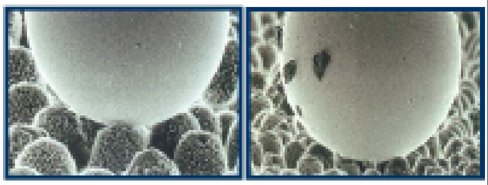
Polimer Kaplı Silikon Yuzey



Lotus Etkisi (2)

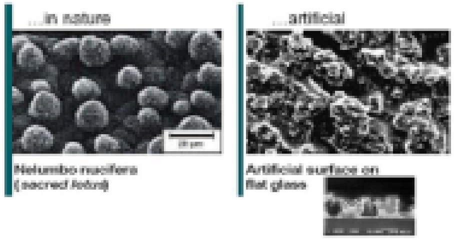
- Kendi kendini temizleyebilme özelliği
-





Şekil 7. Lotus yaprağı üzerinde kirin uzaklaşması (SEM görüntüsü)

Lotus Yaprağı taklit edilirse..



Şekil 8. Doğal lotus yaprağı ve taklit edilmesi ile elde edilen yüzey görünümü

Farklı Yüzeylerde Lotus Etkisi …

- Görev 2: Kendini Temizleme Testi

- Hidrofilik Yaprak
- Kaplanmış Kumaş
- Nano kumaş

Farklı Yapraklarda Lotus Etkisi

- Kendini temizleme özelliği için:
  - Yaprak yüzeyinin hidrofilik olması
  - Su Damlasının 5ºC den daha küçük bir kayma açısı ile kayması

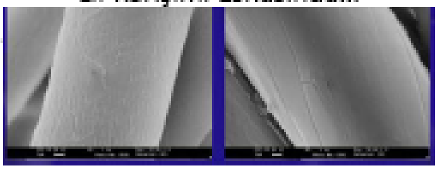
Tekstilde Nanoteknoloji

Lif karışımı esnasında nano boyutlandırma

Nano Kumaş:

(Lif üretimi sırasında polimer çözeltisine nano partiküller katılarak polimer içerisinde hapsedilir).
- Gümüş,
- çinko iyonları,
- karbon karası,
- titanyum dioksit

Lif Karışımı Esnasında…



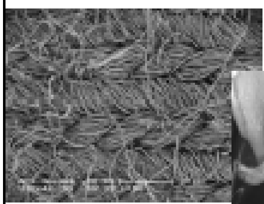
P
a
m

İşlem görmüş
50 nm kalınlığında
titanyum dioksit filmi
ile kaplanmış

Tekstil bitim işleminde materyal içinde boyutlandırma

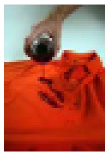
(Kumaş Yüzeyinin nanopartiküller ile kaplanması).

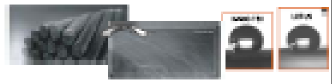
– Nano Ag: Antibakteriyel özellikler
– Nano TiO_2: UV Koruma, kir tutmazlık
– Nano ZnO: UV Koruma, Antibakteriyel özellik



Kaplanmış Kumaş Lifleri
SEM Görüntü

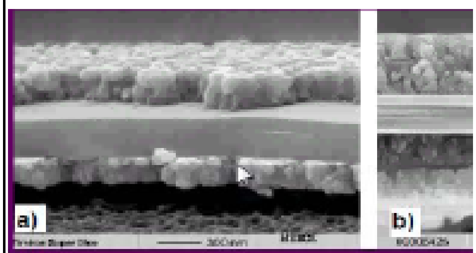
Nano kumaşta Leke Kalır mı?



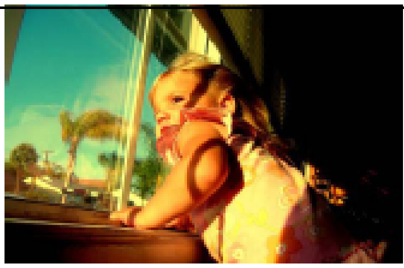


Nano
whiskers

Nano kaplamanın Kullanıldığı diğer alanlar



Şekil. Nano boyutta a)TiO2 kaplanmış n
b) TiO2 /SiO2 /TiO2 kaplanmış mika.

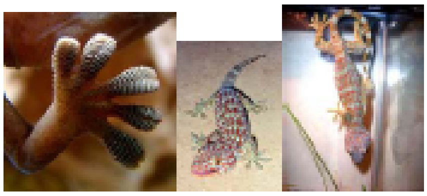


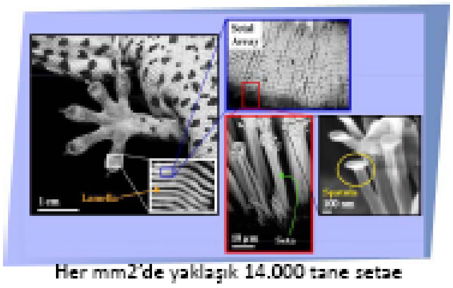
Norveçli bir firma, sprey olarak cam ve diğer yüzeylere uygulanan ince solar bir film geliştirdi. Böylece kaplanan yüzeyler güneş enerjisini hapsedebilecek. 20.09.10, http://students.egfi-k12.org

Biomimetik Gecko

- Yüzeyde tutunmak için

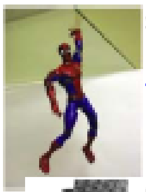
Setae ve yüzey arasında Van der Waals Kuvvetleri



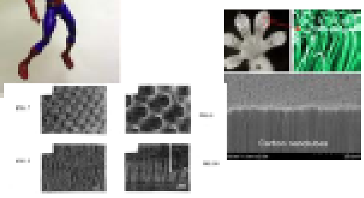


Her mm2'de yaklaşık 14.000 tane setae

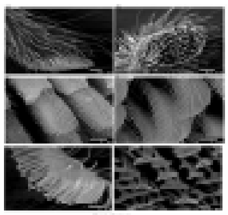
Gecko bantı



Süper yapışkan karbon nanotüp materyal http://www.rsc.org, 10.10.08

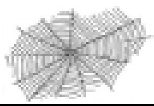


Zıplayan Örümcek

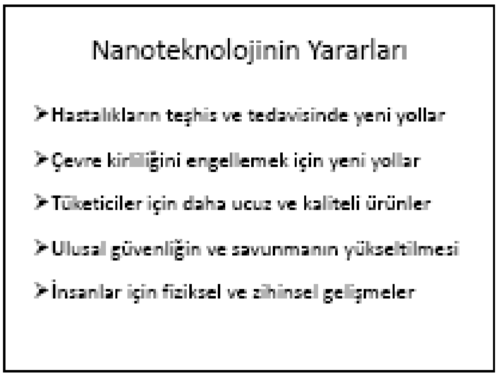


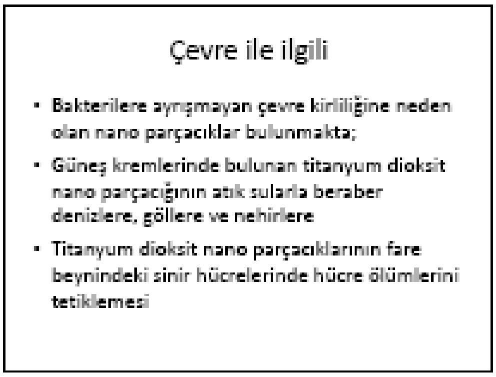
Sentetik iplik ile atmosferdeki suyu tutmak

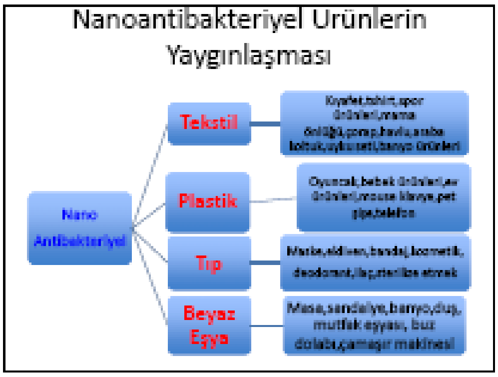
- Pekin, Nanobilim ve Nanoteknoloji Merkezi
- Su damlacıklarını etkili biçimde tutan örümcek ağ lifleri
- Yapay lif geliştirmek
- Havadaki asılı suyu tutmak
- Sanayi üretiminde filtre görevi
- 03.02.10

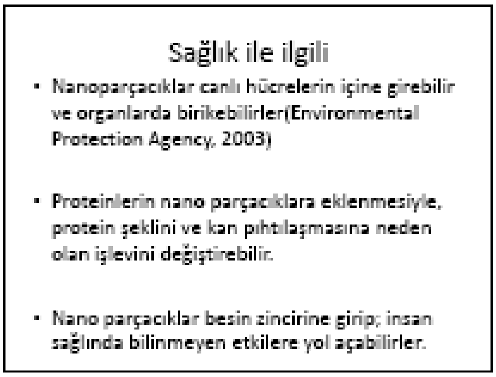


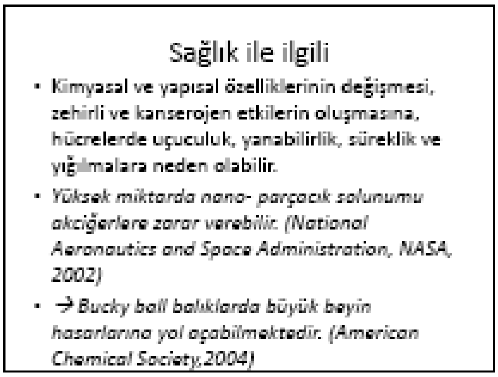
APPENDIX I: PRESENTATION: "RISK & BENEFITS OF NANOTECHNOLOGY"











Güvenlik ile ilgili

- Yüksek miktarda akıllı silahlar
- minyatürleştirilmiş, robot silahlar ve güvenilir uzaktan kapama olmadan yapılan akıllı
- hedef- aramaya yönelik askeri mühimma

Sosyo-Ekonomik Durum ile ilgili

- zengin ve fakir ya da gelişmiş ve gelişmekte olan ülkeler arasında uçurum
- Nano üretim tekniklerinden kaynaklanan milyonlarca işten çıkarılma

Nano etik Boyut

Toplum Farkındalığı:

- Yararların farkında olduğu kadar olası risklerin ve olumsuz sonuçların da farkında olmalıdır.
- bilimsel ve teknolojik olarak okur-yazar vatandaşlık bilinci

Nano ürünler kullanım konusunda ne kadar bilinçliyiz?

Sizin nanoteknoloji Ürün Fikriniz ne?

APPENDIX J: INTERVIEW QUESTIONAIRES

ATÖLYE ÇALIŞMASI ÖNCESİ ÖĞRENCİLER İLE GÖRÜŞME SORULARI

İsim:	**Cinsiyet:**	**Yaş:**
Okul:	**Sınıf:**	**Not Ortalaması:**

Açıklama: Katılmakta olduğunuz bu görüşme, lise öğrencilerinin nanoteknoloji ve nanobilime ilişkin farkındalıklarını anlamak amacıyla düzenlenmiştir. Sorulara içtenlikle cevap vereceğinizi umduğumuz bu görüşmeden elde edilecek bilgiler sadece bilimsel amaçlı kullanılacaktır. Verdiğiniz cevaplar ile çalışmaya katkı sağladığınız için şimdiden teşekkür ederiz.

1. **Kendini kısaca tanıtır mısın?**
2. **Gelecekte hangi alanda çalışmayı düşünüyorsun?**
3. **Nanobilim ve nanoteknoloji terimleri ile daha önce karşılaştınız mı? Evet ise nerede karşılaştınız?**
4. **Nanobilim ve Nanoteknoloji terimleri sizin için ne ifade ediyor?**
5. **Nanobilim ve nanoteknoloji konusu hakkında neler biliyorsunuz?Bildiğiniz Nanobilim ve Nanoteknoloji araştırmaları var mı?**
6. **Nanoparçacık, Karbon nanotüpleri, STM, AFM terimleri sizin için ne ifade ediyor? Daha önce karşılaştınız mı?**
7. **Nanobilim ve Nanoteknoloji hangi riskleri ve yararları beraberinde getiriyor? Bir vatandaş olarak bu konuda yeterli bilgiye sahip olduğunuzu düşünüyor musunuz?**
8. **Nanobilim ve nanoteknoloji hakkında ne merak ediyorsunuz? Ne öğrenmek isterdiniz?**
9. **Gelecekte hangi alanda çalışmayı düşünüyorsunuz?**
10. **Nanobilim ve nanoteknoloji hakkında okulda ders almak ister miydiniz? Ya da bir dersin içerisinde öğrenmek ister miydin?**
11. **Bu atolye çalışmasından beklentileriniz neler?**
12. **Sizin de eklemek istediğiniz birşey var mı?**

ATÖLYE ÇALIŞMASI SONRASI ÖĞRENCİLER İLE GÖRÜŞME SORULARI

İsim:	**Cinsiyet:**	**Yaş:**
Okul:	**Sınıf:**	**Not Ortalaması:**

Açıklama: Katılmış olduğunuz bu görüşme, lise öğrencilerinin nanoteknoloji ve nanobilime ilişkin farkındalıklarını anlamak amacıyla düzenlenmiştir. Sorulara içtenlikle cevap vereceğinizi umduğumuz bu görüşmeden elde edilecek bilgiler sadece bilimsel amaçlı kullanılacaktır. Verdiğiniz cevaplar ile çalışmaya katkı sağladığınız için şimdiden teşekkür ederim.

1. Nanobilim atölyesine katılmış olman nano ile ilgili kavramları anlamanı arttırdı mı? Açıklar mısın?

2. Nanobilim ve Nanoteknoloji terimleri senin için ne ifade ediyor?

3. Nanobilim ve nanoteknoloji ile ilgili hangi konuları daha iyi anladın?

4. Nanobilim ve nanoteknoloji ile ilgili hangi konuları anlamakta zorlandın?

5. Nanobilim ve nanoteknoloji konusu hakkında aklında kalan Nanobilim ve Nanoteknoloji araştırmaları var mı?

6. Atölye çalışmasının en bilgilendirici yanı neydi?

7. Bu atölye çalışmasından öğrendiğin en etkileyici şey neydi?

8. Bu atölye çalışması nanobilim ve nanoteknoloji ile ilgili görüşlerinde nasıl bir değişime sebep oldu?

9. Nanoparçacık, Karbon nanotüpleri, STM, AFM terimleri sizin için ne ifade ediyor?

10. Nanobilim ve Nanoteknoloji hangi riskleri ve yararları beraberinde getiriyor?

11. Nanobilim ve nanoteknoloji hakkında ne merak ediyordun? Atölye çalışmasında öğrenebildin mi?

12. Atölye çalışmasının yeterli düzeyde bilgilendirici olmadığını düşündüğünüz konu neydi?

13. Nanobilim ve nanoteknoloji hakkında okulda ders olarak ister miydiniz? Ya da bir dersin içerisinde öğrenmek ister miydiniz?

14. Bu atölye çalışması olan beklentileriniz nelerdi? Beklentilerinizi karşıladı mı?

15. Bu atölye çalışmasından sonra nanoteknoloji ile ilgili başka araştırmalar yaptınız mı?

16.

17. Atölye çalışmasının içeriğinden çıkarılmasını önerdiğiniz şey var mı, var ise nedir?

18. Atölye çalışmasında mutlaka kalsın dediğiniz şey var mı, var ise nedir?

19. Atölye çalışmasında sıkıcı olan değiştirilmesi gereken şey var mı, var ise nedir?

20. Bu atölye çalışmasından başka nanobilim ve nanoteknoloji ile ilgili başka bir çalışmaya daha katılmak ister miydiniz?

21. Bu atölye çalışmasını geliştirmek ve daha etkili kılmak için sizin önerileriniz nelerdir?

APPENDIX K: BROCHURE

Nanobilim ve Nanoteknoloji

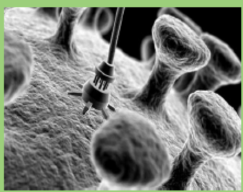
Nanobilim ve Nanoteknoloji Eğitimi tüm dünyada Fen Eğitimi'nde hızla gelişen önemli bir parça olarak görülüyor.

Eğitim ile ilişkilendirilen hedeflerin başında yakın gelecek için ihtiyaç duyulan nanobilim ve nanoteknoloji alanındabilgili ve donanımlı genç bilim insanları.

Yapılan tahminlere göre, 2015 yılına kadar farklı profesyonel çalışma alanlarında çalışabilecek nanobilim hakkında bilgi sahibi olan yaklaşık 2 milyon insana ihtiyaç duyulacak (Roco,2003).

Nanobilim
Sizleri, **Genç Bilim İnsanı Adaylarını,** çağırıyor.

Nanobilim Atölyesi
bir başlangıç olabilir **NE DERSiNiZ?**



Atölye Program
Boğaziçi Üniversitesi, Kuzey Kampüs

9.00- 9.15 Kayıt, Tanışma (Eğitim Fakültesi Binası)

9.15- 9.30 Grupların Oluşturulması

9.30- 12.00 "Nanoşehir" Gezisi (Bölüm I)

- **Sunum: Nanobilim ile Tanışma**
- **Aktivite İstasyonları Ziyaret**
    - Nano Boyut
    - Nanoteknoloji Araçları Keşif
    - Nano Uygulamalar
    - Nano Uygulamalar'ın sırrı ne?
    - Nano Fikrini Üret

12.00- 13.30 Öğle Yemeği
(Güney Kampüs Gezi, Üniversite Tanıtım)

13.30-15.30 "Nanoşehir" Gezisi (Bölüm 2)

- Arge Laboratuarı Ziyaret
- Nanoteknoloji Etiği ve Sosyal Boyutu
- Nano Ürün Tanıtımı

15.30-15.45 Kapanış, Paylaşım

- Nano grup Oluşturma
- Süpriz Ödüller
- Katılım Sertifikası

Nanobilim Atölyesi

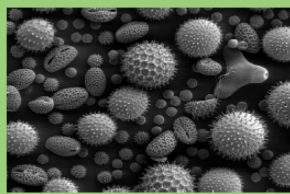
Nanobilim Atölyesi, Boğaziçi Üniversitesi Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü'nde yüksek lisans çalışması olarak geliştirildi.

Araştırmacının amacı, iyi bir Nanobilim Atölyesi tasarlamak; öğrencilerin nanobilim hakkındaki anlamasını ve farkındalığını ölçmek.

Katılımcılar bu atölyeye katılarak, nanobilim ile tanışacak ve de bu araştırmaya gönüllü olarak katkı sağlamış olacaklar.

Katılımcıların görüşleri ve fikirleri doğrultusunda Atölye'nin içeriği geliştirilerek mümkün olduğunca çok "**Nanobilim Meraklıları**"na ulaşmak amaçlanmaktadır.

Gelin hem Boğaziçi **Üniversite**'sinde **bir gün** geçirin, hem de **Nanobilim**'i **keşfedin.**



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