INTEGRATING NANOTECHNOLOGY CONCEPTS AND ITS APPLICATIONS INTO THE SECONDARY STAGE PHYSICS CURRICULUM IN EGYPT

Shaimaa Abdul Salam Selim
Ramadan Abdul-Hameed Al-Tantawi
Samia Ahmad Al-Zaini
Damietta University, Egypt

Abstract

Nanotechnology is very important in our society. Its concepts pertaining to study the unique characteristics of nano-scale material, which, in turn, helps in producing new materials that can be used in the fields of medicine, industry, engineering, agriculture, drugs, communications, defense, space, among others (Ban & Kocijancic, 2011). In response to the lack of these concepts in the Egyptian secondary school Physics curriculum, the current study aim at integrating some Nanotechnology concepts and applications in this curriculum and seek to answer this question: What “nanotechnology concepts and applications” should be teach in the secondary school Physics curriculum in Egypt. To do that, the researchers analyzed the content of Physics curricula in some countries and in the three grades of secondary education in Egypt for the school year 2014-2015, and prepared a list of 52 nanotechnology concepts, to be integrated in the secondary-stage Physics curriculum. These concepts were distributed along five basic units (the first unit included 20 concepts, the second unit 11 concepts, the third and fourth units 8 concepts each, and the fifth unit 5 concepts). On the other hand, twenty one concepts of nanotechnology were integrated into the second-grade secondary school Physics curriculum, distributed along three units (Units one and two included nine concepts whereas unit three included three concepts). Regarding the third grade secondary stage Physics curriculum, 17 nanotechnology concepts were integrated and distributed along three units (the first unit included 3 concepts, the second unit 7 concepts, and the third unit 8 concepts).

Keywords: Nanotechnology concepts and applications, Physics curriculum, secondary stage

Introduction

The world has witnessed several cognitive and technological advances since the third millennium. This is a natural result of scientific breakthroughs and wide-spread technology applications, which had drastic impacts on life styles. These impacts led to more problems pertaining to health, environment and society which require more and more advances in science and research to solve them. Those scientific advances brought the future nearer to the present and added to the accumulation of human civilization in all respects of knowledge.

There has been past reform attempts in contemporary Science curricula, which started in most developed nations to cope with scientific and technological advances. There reforms aimed at promoting a culture of science and a community of scientific practice as a main purpose of science education. They also aimed at developing scientific enquiry, technological design, problem-solving, critical thinking, creativity, and decision making from personal and social perspectives. In spite of those past reforms, prior research indicated that the current science education programs hardly prepare cultured learners who are capable of critical and creative thinking. That is, much emphasis is placed on the cognitive domain of Science issues aloof from their social and personal contexts of use (El-Saadany & Oda, 2006).

It was a challenge for curriculum designers to reconsider school curriculum designs so as to meet the needs of society. Effective Science curricula focus, in terms of their objectives, content, and methodology, on teaching students a reasonable level of functional scientific knowledge necessary for fruitful life-long learning. Optimal Science curricula also aim at teaching students the behaviors, skills, and attitudes pertaining to scientific thinking and developing their scientific interests, values, and attitudes towards Science uses and technological applications as well as their appreciation for the role of scientists in the advancement of societies (Abul-Ezz, 2004).

Literature reviews

Physics has particularly drawn much interest world-wide since most electronic and computer inventions are based on it. That is why most countries are beginning now to produce technology instead of importing it. In this respect, much attention is given to Physics nowadays as one of the most important of sciences that come at the core of modern technology. It gradually turned from merely a branch of natural sciences into the core of other science branches at best.

Leading from that, there has been growing interest world-wide in developing Physics curricula for the purpose of achieving optimal learning outcomes for the benefit of individuals and society. However, this science has remained farther from the issues and interests of society and it is limited to a smaller number of specialists and students compared to other scientific fields of specialty. On account of that, there has been a lot of criticism addressed to Physics curricula in USA and Britain for their incapacity to attract as many students as possible who could be potential scientists in the field. Of these critical views are the following: (Al-Zaanin & Shabat, 2002)

1- The content of Physics textbooks hardly reflects contemporary trends.
2- Rote learning, or verbalized learning, is still common phenomenon in instructional practice.
3- Instruction focuses on segmenting learning, which ignores the principles of sequencing and complementing in selecting and organizing subject matter.
4- Practice is hardly adequate in most schools.
5- Learners are hardly made aware of the nature of integration and interrelation among Physics concepts.
6- Learners are hardly aware of the nature of Physics as a continuous human activity and of the importance of scientific thinking and experimentation in Physics.

In response to these critical views, Physics curriculum-development initiatives grew active world-wide most among which are the following:

- Innovative Physics curriculum initiatives, such as:

Individualized Science Instructional System **(ISIS)** Project, which consists of a large number of micro-materials for learning which could be combined to suit the needs of secondary school students from ninth to twelfth grades. Such calls for innovation took into account new trends and philosophies of Physics instruction delivery in light of the following considerations:

1. Moving from teaching Science for enquiry to teaching it for citizenship based on deep understanding of the nature of Science and its social implications.
2. Moving from teaching Science for developing specialized Science culture to teaching it for developing general culture.
3. Moving from teaching Physics independent from technology to teaching it through integrating Science and technology.
4. Moving from teaching Physics in fixed dogmatic patterns to teaching it in flexible building blocks to be organized according to students' needs.
5. Moving from One-curriculum-for-all to individualized instruction with more emphasis on elective subjects.

These previously-mentioned trends focus on Psychology of learning, general culture, and direct contact with regional issues that concern students' daily life. In this respect Physics curricula could be developed in ways that make it closer to students' interests and help them appreciate the importance of this Science in the technological and economic advancement of society (Redish, Sawl & Steinberg, 1998). This development in curricula and instructional methods should be a continuous process to cope with constant innovations in Physics.

- Approaches for organizing the content of Physics curriculum in the light of innovations in the field

Approaches for organizing Physics curriculum include the following:

- Independent Approach for constructing Physics curriculum

This approach is used for constructing and organizing a separate content related to Physics innovations, as it specifies pertinent Physics issues and underlying topics then organizes them according to a number of criteria such as: modernity and complexity. This approach sheds light on issues pertaining to Physics innovations but it ignores the general constructive scheme of Physics. To make use of this approach, there are a number of considerations to be put into account as follows:

1. Learners should understand the scientific foundations of issues related to Physics innovations, and each issue is tackled in detail according to learners' developmental level.
2. Teaching method and strategy-use skills pertaining to Physics innovations should be developed for the best avail of learners in all grades and stages of learning.
3. Teaching methods pertaining to Independent Approach consume a lot of time and effort, the matter which requires providing other convenient learning resources (Meltzer & Shaffer, 2011).

Research studies pertaining to the use of this independent approach in tackling Physics innovations includes the study of Cahyadi (2008). That study aimed at developing academic achievement and critical thinking skills through a program in Physics innovations based on self-regulated learning. The sample consisted of 35 high school students in Osun, Nigeria. The program was limited to 8 issues in Physics innovations: Expansion of renewable energy production – expansion of nuclear energy production – tremendous progress in space research – production of more modern equipment – computers and the introduction of computers in education – quantum revolution - communication technology - quantum mechanics). Findings revealed the effectiveness of the program in developing awareness of some Physics innovations as well as critical thinking.

The results of ChinLu and Chi's study (2010) consist with those of Cahyadi's (2008). Their study aimed at designing a program based on thinking maps for developing high school Taiwanese students' awareness of Physics innovations. The sample of that study consisted of 65 high school students. Instruments included an achievement test of issues pertinent to

Physics innovations. Physics innovations included some concepts of nanotechnology such as carbon nano-tubes, nano-magnets, magnetic nano-particles, nanoscale thermal conductivity, nanoscale electronic circuits, heat transfer between nanoparticles, nano-optical circuits, and nanoscale gum in electric power generators.

- Inclusive Approach of issues in physics innovations

This approach is used for integrating issues of Physics innovations into pertinent subject matter across Physics curricula. It places emphasis on the integrative structure of Physics. Much criticism has been directed to this approach in as much as it does not logically sequence many of the pertinent issues presented, the matter which calls for selecting issues around one Physics concept at a time or around many closely related concepts and deselecting other irrelevant issues (Meltzer & Shaffer, 2011).

Research studies pertaining to the use of this inclusive approach in tackling Physics innovations include the study of Mills and Sharma (2005). This study aimed at developing Physics curriculum in Western Australia schools and constructing a comprehensive curriculum involving scientific innovations such as communication technology, Laser Physics and its applications, electronic computing, space innovations and applications, and applications of nanotechnology in Physics. Recommendations of that study include: integrating nanotechnology and its applications in academic preparation courses of faculties of education, with more emphasis on the positive side of these applications and the roles they play in solving many societal problems.

- Inclusive Approach of physics innovations across curricula

This approach rests on the premise that issues of Physics innovations are integrated and interrelated with other curricula such as Geography, Economics, and Environment. The critical views directed to this approach include the following:

- It needs an educational teamwork to achieve the necessary integration across curricula.
- It needs more time for practicing the proposed activities.
- It far increases the amount of information within the curriculum (Meltzer & Shaffer, 2011).

Research studies concerned with this approach include the study of Ott and Menz (2010). This study surveyed schooling systems in some developed countries such as the United States of America and China and focused on integration of Nanotechnology applications into Geography curriculum. Examples of these applications include the use of nanotechnology in eliminating environmental pollution; where microscopic machines can remove toxic chemicals from wastewater. Microscopic Robots could also be used to purify water of contaminants. Nanotechnology has also emerged in the production of a number of filters that are used in purifying contaminated drinking water. These filters clean water of bacteria and heavy metallic elements. In this respect, ultra-filtration is one of the most famous filtration methods; in as much as it helps disconnect planktons that range between 2.5 nanometers to 10 nanometers.

Scientists all over the world confirm that nanotechnology will result in a new scientific revolution in the years to come. Therefore, the USA has shown interest in integrating nanotechnology principles and concepts in public school Science curricula. This initiative is very significant in as much as it reflects the needs of labor market for specialized graduates, at school and college levels, in the field of nanotechnology (Healy, 2009).

Several studies (e.g. Berne, 2005; Ekli & Sahin, 2010; El-Sayeh & Hany, 2009; Mahbub & Chowdhury, 2001; Silvovsky, 2010) stressed the importance and necessity of promoting a culture of nanotechnology in schools and universities, especially in developing countries, and training teachers, especially Science teachers, on methods of teaching Science and Nanotechnology. On these grounds, consciousness raising programs of Nanotechnology has become a pressing global need that goes hand in hand with scientific and technological policies of societies. These studies further recommended holding teacher workshops where experiments of developed countries with regard to integrating nanotechnology in school curricula are presented and scrutinized.

Research Problem

In light of pertinent literature reviewed, it is clear that nanotechnology is very important world-wide as a means of transformation in all facets of life. It has much potential in as much as it helps restructure molecules and atoms in matter in such a way that makes it possible to process and produce things on a scale of one hundred nanometers. A nanometer is one of the smallest units, which equals one billionth of a meter or one millionth of a millimeter.

Global Monitoring Report of Education-for-all pointed out that scientists had predicted a promising future for nanotechnology since its first emergence in 1990. That is why industrialized countries allocated millions of dollars for developing it to their best avail. For example, Japan’s funding to support nanotechnology amounted to a billion dollars in 2006. On the other hand, the number of scientists and specialists qualified to work in the field of nanotechnology in the United States amounted to 40,000 and the US budget allocated to this science reached an estimate of trillion dollars up to the year 2015.

A number of projects have been concerned with integrating nanotechnology in different school curricula, such as:

− The integration and education of Nanotechnology Project in Taiwan, organized by the Applied Mechanics Foundation of National Taiwan University in collaboration with the Department of Space Physics at the National University of Cheng Kung. The project lasted from 1/1/2003 until 31/12/2008 (Hwu, 2006).

− Introduction to Nanotechnology Project, which is an initiative of the Australian Government funded by the Australian Office of Nanotechnology, under the auspices of the Research Center in collaboration with the Ministry of Education for the year 2008.

− A multi-tier entry project for Nano-science education, organized by University of Hamburg, Germany in 2008. The project included three educational levels (Calati, Clarte & Keenihan, 2008).

− Online Nanotechnology Project in Edith Cowan University of Western Australia in 2012, which includes a range of educational modules in nanotechnology for learners in grades 1-12 (Karen, Hackling & Masek, 2012).

In light of researcher surveys of science curricula in some developed countries like the United States of America and Japan to learn about scientific concepts offered by the curricula of these countries to their students. Furthermore, studies and research were reviewed pertaining to the local and global development of Physics curriculum in secondary education. Many efforts were also exerted by a number of Arab states such as Saudi Arabia and Jordan to integrate nanotechnology across curricula and develop Science teachers' awareness of this technology. For instances, the Saudi Association of Physical Sciences held a symposium entitled "Sand journey from darkness to civilization", which was held in Umm Al Qura University. This symposium hosted more than 250 members of the Saudi Science Club, which includes advanced and gifted public education and university students as well as teachers of Physics. It aimed at raising their awareness of nanotechnology as one of the most important disciplines of modern science and encouraging its study for the benefit of society development.

The symposium further tackled ways of treating diabetes by packaging insulin with Nano-metric powder dissolved as needed by blood. In addition, it discussed ways of updating the role of science fiction for the development of this science, such as the idea of linking satellites to earth through threads of nanotechnology. Saudi Arabia was also concerned with the establishment of an educational program of Nanotechnology for school and university students and assigned a five-year 30 million SR plan for laboratory and infrastructure development in schools and universities (Al-habashy, 2011).

Egypt is one of the leading Arab countries in the fields of science and cognition. Therefore, it is necessary to continue its leadership in progress and development. It is also necessary for Science curricula to keep pace with this development. However, surveys revealed that the physics curriculum in the secondary stage in Egypt lacks these nanotechnology applications and concepts. Leading from this, the problem of this research lied in the need to integrate nanotechnology concepts into the Physics curriculum in secondary education in Egypt. The research, upon this, investigated this main question: *What are the concepts of nanotechnology to be included in the Physics curriculum of secondary schools in Egypt?*

Research Terminology

Nanotechnology Concepts

There were many definitions that dealt with the concept of nanotechnology. For example, Blonder (2010) defined Nanotechnology concepts as those concepts pertaining to the study of the unique characteristics of nano-scale material, which, in turn, helps in producing new materials that can be used in the fields of medicine, industry, engineering, agriculture, drugs, communications, defense, space, among others.

Nanotechnology concepts could be procedurally defined in this research as an abstract description of nano-scale materials and tools in a size-range between (1-100) nm and the study of their shape and structure in addition to their treatment and control, at this size-level, in order to produce new materials with unique characteristics that can be used in different fields of life, such as medicine, engineering, agriculture, industry, construction, energy and others.

Research Objectives

This research aims at proposing a framework of the nanotechnology concepts and applications that needs to be integrated in the Physics curriculum of secondary schools in Egypt.

Research Importance

The importance of this research lies in the following parameters:

1. Shedding light on the status quo of the secondary school Physics curriculum and how far nanotechnology applications are available in it.
2. The list of nanotechnology concepts and the research findings may hold benefits to curriculum and syllabus developers as well as Science teacher preparation program developers.

Research Tools and Materials

The following tools were prepared by the researchers:

− A list of concepts and applications that need to be integrated into the secondary school Physics curriculum in Egypt.

− A questionnaire for measuring the sample's views of the concepts and applications to be integrated into the secondary school Physics curriculum.

Research Method

The descriptive method uses in this research to describe and analyze pertinent literature, theories and projects as well as the content of sample Physics curricula in Arab and foreign countries. It was also used in preparing the list of nanotechnology concepts and applications to be integrated in the secondary school Physics curriculum in Egypt.

Sample of the Study

a. **Content sample:** It included the Physics textbooks of the three stages of secondary education for the school year 2014-2015, which were content-analyzed for the purposes of the study.

b. **Human sample:** It included 20 Physics teachers, 10 Physics supervisors, 10 Physics professors, and 9 professors of curriculum and instruction of Science who were selected at random for the purpose of gauging their views with regard to the proposed Physics curriculum in light of nanotechnology concepts.

To answer the research question, stating: "What are the nanotechnology concepts and applications that need to be integrated in the secondary-stage Physics curriculum in Egypt?", the researchers:

1. analyzed the content of Physics curricula in the following countries: United States of America "California", Japan, England, and China). The content-analysis results showed that nanotechnology concepts were included in the Physics curriculum of California, USA, in 40.7% of the total percentage of the Physics concepts included in the curriculum. In the Physics curriculum of Japan, nanotechnology concepts were 41% of the total of Physics concepts, in the Physics curriculum of England they were 36.4% and in the Physics curriculum of China they were 38%.

2. analyzed the content of Physics curricula, in the three grades of secondary education in Egypt for the school year 2014/2015, through the following procedures:

− Preparing the analysis tool, which is a list of nanotechnology concepts and applications to be integrated in the secondary stage Physics curriculum

− Determining the sample of analysis in the Physics curriculum of the secondary stage.

− Determining the units of analysis, which were the nanotechnology concepts and applications proposed for integration.

− Determining categories of analysis, represented in the content of the Physics curriculum in the three grades of secondary schools in Egypt.

− Analysis criteria were determined as follows:

a. The Physics curriculum in the three grades of the secondary stage was analyzed through counting the pages of textbooks and excluding pages that contain the following: Introduction, index, tables, illustrations, maps, pictures, questions and exercises.

b. Analysis was attempted at three levels as follows:

1. The extent to which categories of analysis were addressed (addressed - does not address)

2. The way categories of analysis were addressed (implicitly – explicitly)

3. The level at which categories of analysis were addressed (In summary – in detail)

− Analysis objectivity: to guarantee objectivity of analysis, validity and reliability were achieved as follows:

a. Analysis validity: After conducting the content-analysis process, a colleague who had fairly the same experience and knowledge attempted the content-analysis again of different samples of the same textbooks analyzed by the researcher, and the second content-analysis attempt revealed the same results.

b. Analysis reliability: After conducting the content-analysis, it was re-conducted with time-difference of four weeks using Holsti equation (Teaima, 2004) for calculating the correlation percentage between the two times, which was highly significant at 0.87.

Content-analysis results revealed that the total number of physics concepts integrated was 103 concepts, with no trace for nanotechnology concepts therein. This result verifies the research hypothesis stating that “the current Physics curriculum at the secondary stage in Egypt included no nanotechnology concepts.

3. Analyzed the content of some projects that focused on the integration of nanotechnology into different school curricula, such as:

− Nanotechnology Integration and Education Project in Taiwan, organized by the Applied Mechanics Foundation of National Taiwan University in collaboration with the Department of Space Physics at the National University of Cheng Kung. This project lasted from 1/1/2003 till 31/12/2008. The content-analysis results revealed that the total number of physics concepts in the secondary stage Physics curriculum in Taiwan was

86 concepts, and the number of nanotechnology concepts was 23; namely 26.7% of the total number of physics concepts.

− Entry to Nanotechnology Project, an initiative on the part of the Australian government financed by the Australian Bureau for Nanotechnology, under the auspices of the Research Center in collaboration with the Ministry of Education in 2008. The content-analysis results revealed that the total number of physics concepts in the secondary stage Physics curriculum in Australia for the year 2008 was 92 concepts, and the number of nanotechnology concepts was 27; that is, 29% of the total number of physics concepts.

− Multi-tier Nano-science Education Project, organized by the University of Hamburg, Germany in 2008. It consisted of three educational levels. The content-analysis results revealed that the total number of physics concepts in the secondary stage Physics curriculum in Nordrhein-Westfalen, Germany was 116 concepts, and the number of nanotechnology concepts was 34; that is, 29% of the total number of physics concepts.

− Online Nanotechnology Project in Edith Cowan University of Western Australia in 2012, which includes a number of educational modules on nanotechnology for learners in grades 1-12. The content-analysis results revealed that the total number of physics concepts in the secondary stage Physics curriculum 97 concepts, and the number of nanotechnology concepts was 36; that is, 37% of the total number of physics concepts.

The initial version of the list of nanotechnology concepts, to be integrated in the secondary-stage Physics curriculum in Egypt, was prepared in light of pertinent Arab and foreign Science research as well as content analyses of Physics textbooks and projects concerned with nanotechnology integration into different curricula. The list contained the following:

− 52 nanotechnology concepts were integrated into the first-grade secondary stage curriculum, distributed along 5 units (the first unit contained 20 concepts; the second unit 11 concepts; the third and fourth units contained 8 concepts; and the fifth unit contained 5 concepts).

− 21 nanotechnology concepts were integrated into the second-grade secondary stage curriculum, distributed along 3 units (the first and second units contained 9 concepts and the third unit contained 3 concepts).

− 17 nanotechnology concepts were integrated into the third-grade secondary stage curriculum, distributed along 3 units (the first unit contained 3 concepts; the second unit contained 7 concepts; and the third unit contained 8 concepts).

− The list was submitted to a panel of jurors in the field of Science instruction at faculties of education and Physics at faculties of Science

(N=19) for validation. The jurors confirmed the importance of those concepts and their relevance and appropriateness to the developmental characteristics of the students. The researcher made all changes and modifications as suggested, most important of which was adding some applications of nanotechnology. Examples of applications added were: Nano circuit for protection against risks of electromagnetic waves, solar nano-satellites, and solar cells and nanotechnology. The list was, then, prepared in its final version, with a total of 91 concepts of nanotechnology. The table below illustrates the number of nanotechnology concepts and applications integrated into the secondary stage Physics curriculum:

Table 1 Number of Nanotechnology concepts and applications integrated into the secondary stage Physics curriculum

Grade	The unit as it is in the current curriculum	Number of Nanotechnology concepts and applications proposed for integration
First Grade secondary	Unit 1: Physical quantities and units of measurement	20 concepts as follows: Nano-scale –Nanotechnology pioneers – Nanotechnology principles of excellence – size of nanoparticles – form of nanoparticles – structure of nanoparticles – Nanoparticle transparency – Nanoparticle solidity – Degree of atoms assembly (clustering) in nanoparticles – Distribution of atoms in nanoparticles – Quantum points - Uses of quantum points – Features of quantum points – Forms of nano-materials – One-dimensional nano-materials – Two-dimensional nano-materials – Three-dimensional nano-materials – Mechanical properties of nano-materials – Optical properties of nano-materials – Electrical properties of nano-materials.
	Unit 2: Motion	11 concepts as follows: Quantitative confinement of atoms in nano-materials – motion of nanomaterial – Quantum crystals – Fullerene – Silver nanoparticles – Atomic Force Microscopy (AFM) – Scanning Probe Microscopy (SPM) – Benefits of Scanning Probe Microscopy – Scanning Tunneling Microscopy (STM) – Applications of nanotechnology in motion – Nano-robots
	Unit 3: Work and Energy in daily life	8 concepts as follows: Carbon technology – carbon efficiency – Alternative energy and nanotechnology – Solar cells and nanotechnology – Nano-scale solar satellites – Nano-scale catalysts – Developed fuel cells – Reducing energy consumption.
	Unit 4: Thermal energy and its applications in daily life	8 concepts as follows: Thermal properties of nanomaterials – Measuring device of the temperature of a nanoparticle – Change in the thermal resistance of nanomaterials – Thermal energy of a nanoparticle – Nano-sensors and harmful gases – Heat insulating glass – Thermal treatment using nanoparticles – Thermal expansion of nanomaterials.
	Unit 5: Magnetic force and its applications	5 concepts as follows: Nano-magnetic force – nanotechnology magnet – Nano-circle of protection against risks of electromagnetic waves – Overcoming some damages of

Table 1 Continued

Grade	The unit as it is in the current curriculum	Number of Nanotechnology concepts and applications proposed for integration
Second Grade secondary		electromagnetic waves using nanotechnology – Devices for measuring waves using nanotechnology.
	Unit 1: Waves	9 concepts as follows: Devices for measuring waves using nanotechnology – Optical properties of nanoparticles – Nano-scale optical devices – Blue Butterfly and the phenomenon of light diffraction – Nano-scale optical stimuli – Sound behavior nanotechnology – Sound overlap nanotechnology – Sound diffraction nanotechnology – Ear nanotechnology
	Unit 2: Properties of Fluids	9 concepts as follows: Nano-scale Fluids – Low fluid Reynolds number – The impact of surface charge and Debye layer – Nano Gold – Nano Gold applications – Molecular Detectors with Nano-pores – Nano structures – electromechanical Nano-systems – one-particle sensing.
	Unit 3: Heat	3 concepts as follows: Highly sensitive sensors – Silver nanoparticles – Nano sensors.
Third Grade secondary	Unit 1: Heat	3 concepts as follows: Nano-technology coolers – Nano ceramic Films – The role of nanotechnology in refrigerators' functioning.
	Unit 2: Electrical and electromagnetic power	7 concepts as follows: Nano-circuits – Nano-electronics – Nanowire industry – Electronic Nano-devices – Nano optical resistance – Nanotechnology electric generators –Nanotechnology Computer memory
	Unit 2: Introduction to modern Physics	9 concepts as follows: Nano lasers – Properties of nano-scale laser beam – Wavelength of Nano-laser – Nano-laser applications – Metal rubber – Data storage unit – Nano-scale gum – Nano-car.

A questionnaire of nanotechnology concepts and applications proposed for integration into the Physics curriculum across the three grades of the secondary stage was prepared and submitted for validation. The questionnaire included three alternatives responses (highly appropriate - moderately appropriate - not appropriate). It was administered to a sample of 20 secondary school Physics teachers, 10 supervisors, 10 professors of Physics at Faculty of Science, and 9 professors of curriculum and instruction of science, in order to check their views about the content appropriateness for students. Each individual of the sample was asked to mark (√) in front of each concept in the response slot provided.

The relative weight of each concept in the questionnaire[1] was calculated in order to classify concepts into three ranks through the following:

− Estimating frequency of recurring responses for each of the three alternatives provided in the questionnaire and assigning a numerical value for each slot representing each alternative response: “Highly appropriate” was assigned 3 points, “moderately appropriate” was assigned 2 points and “not appropriate” was assigned 1 point. “No background knowledge of nanotechnology concepts” was assigned zero point.

− Calculating the relative weight of each concept by multiplying the number of frequencies/iterations in each slot by its specified numerical value, and then summing the end-result.

The range of each of the three ranks was calculated as follows:

- The relative weight of first-rank nanotechnology concepts ranged between 120 and 147 with a percentage of 91.7%.
- The relative weight of second-rank nanotechnology concepts ranged between 112 and 119 with a percentage of 44.9%.
- The relative weight of third-rank nanotechnology concepts ranged between 91 and 111 with a percentage of 11.55%.

The following table shows the distribution of first, second and third ranks of the proposed nanotechnology concepts integrated into the Physics curriculum:

Table 2 Distribution into first, second and third ranks of the concepts of nanotechnology

Grade	Unit	Topic	Nanotechnology Concepts	Rank		
				First	Second	Third
First Grade secondary	physical quantities and units of measurement	physical measurement	Nano-scale – Nano-technology pioneers – Nano-technology principles – size of nanoparticles – shape of nanoparticles – structure of nanoparticles – transparency of nanoparticles – solidity of nanoparticles – forms of nanomaterials – one-dimensional	13	2	---

Table 2 Continued

Grade	Unit	Topic	Nanotechnology Concepts	Rank		
				First	Second	Third
First Grade secondary			nanomaterials – two-dimensional nanomaterials – three-dimensional			

[1] Questionnaire results regarding the concepts of nanotechnology to be integrated into the secondary school Physics curriculum in Egypt.

		nanomaterials – mechanical properties of nanomaterials – visual properties of nanomaterials – electric properties of nanomaterials			
	scalar and vector quantities	Degree of atomic clustering in nanoparticles – distribution of atoms in nanoparticles – quantum dots – uses of quantum dots – properties of quantum dots.	4	1	---
Motion	forms of motion	Quantitative confinement of atoms in nanomaterials – motion of nanomaterial – Quantum crystals – Fullerene – Silver nanoparticles – Atomic Force Microscopy (AFM) – Scanning Probe Microscopy (SPM) – benefits of Scanning Probe Microscopy – Scanning Tunneling Microscopy (STM)	5	3	---
	Motion in uniform acceleration	Nanotechnology applications in motion – Nano-robotics.	---	2	---
Work and Energy in daily life	Work and Energy	Carbon technology - carbon efficiency - Alternative energy and nanotechnology – Solar cells and nanotechnology – Nano-scale solar satellites – Nano-scale catalysts – Developed fuel cells – Reducing energy consumption.	---	8	---
Thermal energy and its applications	Internal energy and temperature	Thermal properties of nanomaterials – Measuring device of the temperature of a nanoparticle.	---	2	---
	Thermal energy	Change in the thermal resistance of nanomaterials – Thermal energy of a nanoparticle – Nano-sensors and harmful gases – Heat insulating glass – Thermal treatment using nanoparticles.	---	5	---

Table 2 Continued

Grade	Unit	Topic	Nanotechnology Concepts	Rank First	Rank Second	Rank Third
Second Grade secondary		Thermal expansion	Thermal expansion of nanomaterials.	---	---	1
	Magnetic force and its applications	Magnetic force	Nano-magnetic force – nanotechnology magnet – Devices for measuring waves using nanotechnology.	---	2	1
	Waves	Wave motion	Devices for measuring waves using nanotechnology – Optical properties of nanoparticles – Nano-scale optical devices – Blue Butterfly and the phenomenon of light diffraction – Nano-scale optical stimuli.	---	4	1
		Sound	Sound behavior nanotechnology – Sound overlap nanotechnology – Sound diffraction nanotechnology – Ear nanotechnology	---	---	4
	Fluids	properties of static fluids	Nanoscale Fluids - Low fluid Reynolds number – The impact of surface charge and Debye layer – Nano Gold – Nano Gold applications.	2	1	2
		properties of moving fluids	Molecular Detectors with Nano-pores – Nano structures – electromechanical Nano-systems – one-particle sensing.	---	1	3
Third Grade secondary	Heat	Gas laws	Highly sensitive sensors – Silver nanoparticles – Nano sensors.	3	---	---
		Low Temperature Physics	Nano-technology coolers – Nano ceramic Films – The role of nanotechnology in	3	---	---

			refrigerators' functioning.			
	Electrical and electromagnetic power	Electric current and Ohm's Law	Electronic Nano-circuits – Nano-electronics.	2	---	---
		Magnetic effect of electric current and electric current devices	Nanowire industry – Electronic Nano-devices – Nano optical resistance – Nanotechnology electric generators	4	---	---

Table 2 Continued

Grade	Unit	Topic	Nanotechnology Concepts	Rank First	Second	Third
	Introduction to Modern Physics	Electromagnetic induction	Nanotechnology Computer memory	---	1	---
		Laser	Nano lasers – Properties of nano-scale laser beam – Wavelength of Nano-laser – Nano-laser applications.	4	---	---
		Modern Electronics	Metal rubber – Data storage unit – Nano-scale gum – Nano-car.	4	---	---

It is clear from the previous examples that the most suitable concepts to the students' characteristics are those presumably integrated in the first unit entitled "physical quantities and units of measurement" in the secondary school Physics curriculum. That is, 21 concepts of nanotechnology were included in unit one and they ranked the first in a three-level distribution scale among other nanotechnology concepts. On the other hand, the least suitable concepts to the students' characteristics are those included in the "waves" unit and "fluids Science" unit in the second-grade secondary stage, which ranked the third among other nanotechnology concepts. Jurors attributed this to the fact that the concepts integrated in these two units were too abstract for the students to understand at this stage.

Conclusion

In the light of studies and researches related to worldwide projects incorporating nanotechnology concepts and its applications in different stages of education, we conclude that:

First: Our current era is known as the information age; hence, it's crucial to develop various science curriculums in the light of all scientific innovations. Nanotechnology is such a science that we need to improve, highlight the positive effect of its applications, and its role in solving many society issues.

Second: Many studies have focused on the integration of nanotechnology concepts with physics approach in high school phase, and the effectiveness of that has been proven in the way high school students have improved the use of these concepts.

At the end, by the present research we recommend the following:

- Physics curricula should be continuously analyzed and developed to cope with scientific, technological and educational innovations on the one hand and the needs of the Egyptian society and its individuals on the other hand.
- Physics curricula should be responsive to students' needs and the scientific and mental skills required, qualifying them for a technological-scientific society.
- There is a need for an academic program to develop secondary school Physics teachers' awareness of the importance of nanotechnology concepts, applications and methods of teaching.

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