# Introducing topics on nanotechnologies to middle and high school curricula

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ABSTRACT: The paper presents examples of good practice in nanotechnology education, ongoing activities, experiments, computer-supported programs, materials for students as well as for teachers, etc. The experiments described are simple to conduct and only resources that are generally available are needed. Technology education could use nanoscience and nanotechnology to evoke a dialogue on important issues, for example the relationships between science, technology and society. Concerning the fact that nanotechnology is reality, not a science fiction, it should also be included in curricula in pre-higher education. Currently, there are no topics related to nanotechnology in Slovenian education at the level of middle schools. The paper, therefore, includes suggestions for inclusion of some topics related to nanotechnology into middle school curricula within the existing compulsory subject engineering and technology, and in one of the elective subjects.

## INTRODUCTION

*Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale* [1].

The term nanoscience is derived from the distance of a nanometre (nm), one-billionth of a metre, $10^{-9}$ m. For comparison, a single human hair is about 80,000 nm wide, a red blood cell is approximately 7,000 nm wide, and a water molecule is almost 0.3 nm across. People are interested in the nanoscale (which is defined to be from 100 nm down to the size of atoms (approximately 0.2nm)) because it is at this scale that the properties of materials can be very different from those at a larger scale.

*Nanotechnologies* are the design, characterisation, production and application of structures, devices and systems by controlling shape and size on a nanometre scale [1].

*Nanomaterial* is an object that has at least one dimension on the nanometre scale (app. 1-100 nm); material can be in one dimension (very thin surface coatings, films, layers), in two dimensions (nanowires, nanotubes, fibres) or in all three dimensions (nanoparticles, quantum dots, nanoshells, nanorings, micro) [2].

Although modern nanoscience and nanotechnology are quite new, nanoscale materials have been used for centuries. For example, alternate-sized gold and silver particles created colours in the stained glass windows of medieval churches hundreds of years ago.

Regarding the fact that nanomaterials with their specific and unusual properties are becoming more and more a part of our everyday life, it seems appropriate to introduce these topics to students before they enter higher education. According to some analysis of the educational significance of nanoscience and nanotechnology in scientific and technological literacy, the educational importance of nanoscience and nanotechnology is growing. It was concluded that nanotechnology topics may be efficiently presented to students aged 12 to 18 and that the motivation of these students for such topics is high. A number of different and interesting programmes and projects through the world are dealing with nanotechnology in education. In several European countries, novel teaching and learning materials on nanotechnology are currently being piloted within the *Nanoyou* project.

## REVIEW OF THE CURRENT SITUATION

There are many resources, which include information about nanotechnologies, nanoscience and materials, for teachers/trainers. Some resources specifically cover ethical, legal and social aspects, along with safety.

In the following section, a few resources are briefly introduced.

Almost everything about nanotechnology for schools can be found on a Web page of the University of Cambridge links to interesting Web pages about nanotechnology, articles, etc [3].

*Nanoyou* (Nano for Youth) is a project that aims to increase young people's basic understanding of nanotechnologies and to engage in the dialogue about its ethical, legal and social aspects [2]. Nanoyou has prepared an educational curriculum for young people aged 11-18 and a wide range of activities in science centres for those in the 18-25 age group.

On the Web portal, virtual activities for students are available, as well as dissemination material, a virtual forum, where students can engage in different dialogues and a strong network, which allows different institutions and schools to share their experiences and resources.

*Nanokids* is an educational outreach programme, which is dedicated to increasing public knowledge of the nanoscale world and the emerging molecular research and technology that is rapidly expanding internationally [4]. The Nanokids visual concept utilises universally recognised forms exhibiting human characteristics to instruct, motivate and entertain. On the Web page, there are introductory videos, workbooks, sample tests and teacher resources.

*Nanotech kids* is an interactive programme that shows what nanotechnology and nanoscience is and has many games and other activities [5].

*Nanonet* organises three types of Nanotech Schools to train young researchers for further development of nanotechnology: Nanotechnology Summer School, Cross-sectional School and Young Researchers Exchange Programmes [6].

*Understandingnano* - Understanding Nanotechnology is a Web site dedicated to making nanotechnology concepts and applications understandable by anyone [7]. On this site, one can find explanations of nanotechnology concepts, links to articles and resources, such as manufacturers' Web sites and nanotechnology stories in the news. They also created lesson plans to help high school and middle school science teachers provide an introduction to nanotechnology in a classroom setting.

*National Nanotechnology Initiative* (NNI) is the biggest US initiative on nanotechnology [8]. There are higher education programmes, teaching resources, material for students aged up to 18 years (K-12), workforce and training. The Web page is very useful for higher schools.

*Accessnano* is a unique, cutting-edge nanotechnology educational resource designed to introduce accessible and innovative science and technology into Australian secondary school classrooms [9]. This resource has a lot of very well done material and an industry-application focus.

*NISE Network* is a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering and technology [10]. This is one of the best networks of informal educators and it has material for schools, as well as science exhibits, nano-days, experiments, etc.

*Nanomission* is an engaging learning experience, which educates players about basic concepts in nanoscience through real world practical applications from microelectronics to drug delivery [11]. Through sponsorship, they aim to make the PC version of the game, including a *teachers* version, which contains lesson plans and on-line support, available free to schools and colleges throughout the world.

The *NanoSense* project (2004-2008) is addressing the question of how to teach nanoscale science at the high school level [12]. Working closely with scientists and educators, the project created, tested and disseminated four curriculum units to help high school teachers and students understand nanoscale science. The project hosted workshops to introduce teachers to the materials, and held working meetings with experts and practitioners to identify and clarify major concepts and learning goals for nanoscience education.

The Materials Research Science and Engineering Center has an educational portal [13]. The organisation aims to enhance public understanding of science and engineering through a central theme of *Exploring the Nanoworld, Innovating through Materials* using Web dissemination to a range of educators, presentations in public venues, and contributions to popular publications and media. On this portal very interesting lesson plans, exercises, descriptions of experiments (demonstrations), courses, activities and programmes, etc, can be found.

*AQnoHUB* provides on-line simulations, learning modules, and interactive tools for learning about nanotechnology [14].

DESCRIPTION OF ACTIVITIES

It is very important how nanotechnology is introduced in schools. A lot of work has already been done in this field. In previously mentioned resources, quite a lot of materials for teachers and also for students can be found. However, nanotechnology is a theme difficult to present, therefore, it is important that it is presented in the right way!

In this section, experiments, videos, interactive games and some fun activities for children are introduced. It is recommended that nanoscale concepts are made as picturesque as possible and with examples from everyday life. Examples of introducing nanoscale are shown in Figure 1 and Figure 2.


Figure 1: The scale of things [15].

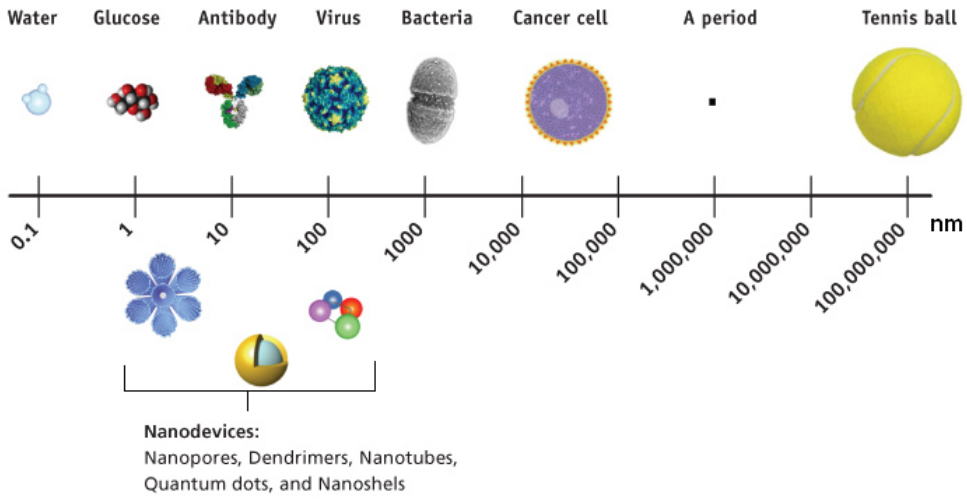


Figure 2: From macro-materials to atoms. Nanomaterials and nanodevices that are of interest in nanotechnologies are in the lower end of the scale (1-100 nm) [16].

Experiments

Nanoyou has collected together a number of experiments, which include background reading for teachers and a protocol, as well as background reading for students, laboratory worksheets and videos. Some of the documents are available adapted to two age ranges. Descriptions are available on [17].

*Example: Experiment on Natural Nanomaterials*

This experiment is based on natural nanomaterials, which can be found around us. For this experiment, extensive teacher documents and student laboratory worksheets have been prepared (separately for students aged 11-13 and 14-18), student background reading and a Power Point presentation.

Figure 3: Examples of nanomaterials - from student laboratory worksheet (age 11-13) [17].

Gorazd Planinšič described a simple didactical model of atomic force microscope (AFM), which can be used as a concrete example for an introductory presentation of nanotechnology in school (see Figure 4) [18].

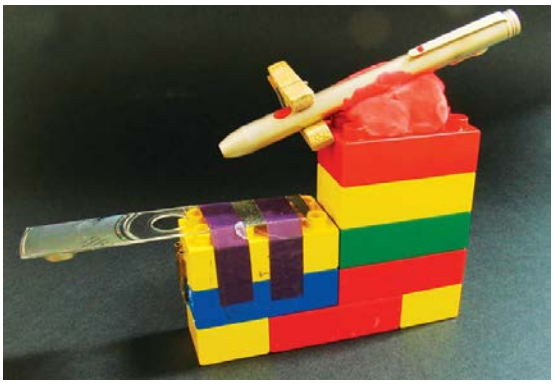

Figure 4: Microscope AFM [18].


Figure 5: The Nanotechnology Board Game [19].

Videos

A very effective way to introduce nanotechnology to students is with videos. Nanonet is a Web site that presents video explanations of the nanotechnology world, what nanotechnology is, presentations about the size of a nanometer, introduction of nanotechnology from biological aspects, and videos about electronics, environment and energy [5]. All these videos show nanotechnology in a very simple and guided way.

Interactive Games

Several interesting games are available and they are an interesting way of providing education that is especially suitable for middle schools. In general, they are jigsaw puzzles, memory games and other types of material. Examples can be found on the Web sites of Nanoyou [2], Nanotech Kids [5], Nanozone [20], whereas more pretending games are hosted on Nanomission [11].

NanoVenture: The Nanotechnology Board Game (Figure 5) explores the connections between science, specifically nanotechnology, and society. In this game, players become leaders of a new country. The leaders are challenged to make decisions regarding their country's use of nanomaterials and nanotechnology, while maintaining a high approval rating from the citizens of the country. These decisions require players to analyse carefully the interplay of technological advances, regulations, public perception and risk, while also learning about the emerging field of nanotechnology [20].

INTRODUCTION OF NANOTECHNOLOGY IN SCHOOLS AND SUGGESTIONS FOR INCLUSION OF NANOTECHNOLOGY TOPICS IN SLOVENIAN CURRICULA

The definition of nanotechnology is perhaps not so easy to understand, but this is an emerging field of modern technology. All citizens will soon need some kind of *nano-literacy* in order to navigate through some of the important

science-based issues related to their everyday lives and society. Education about nanotechnology should be gradual and introduced at early ages in pre-school setting and later continued up to the high school level.

In several European countries, various institutions are offering exhibitions for schools and the public or organising visits to educational institutions. Also available are workshops, seminars, interactive lectures and many on-line resources, providing information and games for scholars. Various kits are being published. Examples of such institutions are the Saarlab Initiative, Nanotruck…, University of Cambridge, Nanoyou project, NanoBioNet initiative, and various science museums [21][22].

Furthermore, in addition to incorporating such subject matter into the formal educational system, demands for nanoscience and nanotechnology education have also spawned several informal outreach projects worldwide. These initiatives include educational Web-based materials directed at the public, as well as exhibitions in museums and science centres.

As a first step, in Slovenia, schools could join the Nanoyou schools community. They have an established programme and materials for teachers/trainers, as well as students. Unfortunately, the teaching of engineering and technology in Slovenian general education is being carried out only from the $6^{th}$ to $8^{th}$ grades (11-13 years). Curricula for corresponding classes are extensive; therefore, nanotechnology should be introduced in small steps and in an interdisciplinary manner (especially in conjunction with biology, chemistry and physics).

The ideal solution would, of course, be an initiative to introduce engineering and technology education in the $9^{th}$ grade. That class would be dedicated to modern technologies. Another possibility would be an elective subject with same relevant content. Courses for teachers dealing with nanotechnology would be an inevitable task, if we really wanted to introduce nanotechnology into Slovenian schools.

Nanotechnology could be presented to students as technology days, on which teachers would prepare activities for students (experiments, demonstrations, etc). Examples of good practice from foreign countries are Nanodays - a nationwide festival of educational programmes about nanoscale science and engineering [10].

Taking into account the amount of well-prepared materials in the field of nanotechnology education, the introduction of such activities in Slovenian schools should not be too difficult.

There are numerous reports that emphasise the need to *revitalise* science teaching in school, particularly at the high school (14+) level. It is also often recommended in those reports that problem-based learning be encouraged, where teaching is conducted through an inductive method. This should be combined with numerous *hands-on* activities to allow students to see science for themselves, and then learn and understand the theoretical explanation of what they see [2].

## CONCLUSIONS

Taking into account that nanotechnology is a *modern trend*, it would be wise to introduce it to the students as early as in primary schools. Implementation of nanotechnology education into schools is a common process worldwide; therefore, Slovenia cannot afford to delay compared with the rest of the world.

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