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Nanothinking as a concept of Citizenship Education for 21st Century Europe

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Abstract

Knowing how to live together healthily, safely, and humanely in society is certainly a worthwhile cause. It is also a real challenge for those who educate young citizens of today. This paper outlines how nanotechnology education can be considered a fundamental discipline of the 21st century educational systems for supporting the development of responsible citizenship, since it touches the most significant areas of the wellbeing of every citizen – health, safety and security, and the environment – which occupy a privileged position in all cultures and all considerations. Citizenship education does not rest on acquisition of explicitly theoretical knowledge. Rather, it targets the development of civic behaviour in all inhabitants of a given territory (one they identify with) and ultimately throughout the entire world.

Keywords: *nanoeducation, nanothinking, nanomanagement, citizenship education.*

Introduction

One decade into the 21st century, people and governments worldwide face decisions involving complex scientific considerations or innovations in technology. The new participative democracy demands that citizens be asked to make judgments, and even vote, on subjects about which they know very little – the desirability of cloning animals and human beings, creating novel biological organisms, manipulating matter at an atomic scale, eugenics, genetic engineering, GM foods, nano-products, and other great moral and economic questions of the day. Therefore, educational systems have to produce a steep increase in students' intellectual potential in order to provide responsible answers to such complex questions, previously the domain of university researchers.

Educational environment is becoming a new supercomplex system with a constantly changing intellectual pattern. However, the structure of our universities has changed very little in the past fifty years. In many scientific fields, much of the most exciting discovery potential is located between the boundaries of traditional disciplines. A great deal of novel multifunctional nanomaterials, advanced nanodevices, new nano-based products and processes are designed and developed by team effort of materials' scientists working with chemists, biologists, physicists, information technology experts, and engineers. It is thus apparent that we need to create new types of universities, which have 'departments without walls' (Allianz Center for Technology, 2010; EPA, 2009).

1. Nanotechnology as the imperative for educational redesign

Rapid technological changes have dramatically altered students' educational needs. The simplest explanation for the current need of educational change is that we, as society, have outgrown our educational systems disseminating core knowledge and building basic skills. With the advent of the information age, and now the beginning of new technologies age, the educational model of today no longer meets our societal needs. In fact, it is limiting the ability of teachers and students to adapt to the 21st century.

Nanotechnology is an exciting area of scientific research and development that is truly multidisciplinary. It is worth mentioning that the prefix *'nano'* originates from the Greek word meaning '*dwarf*' and in modern science means *'a one-billionth (10^{-9}) part'*. Consequently, the talk is about researches of the world at the scale which is one-billionth (10^{-9}) of a meter in size - the nanometer, (or one millionth of a millimetre), which is tiny and unseen. A single human hair is about 80,000 nm wide, a red blood cell is approximately 7,000 nm wide, a DNA molecule is 2 to 2.5 nm, and a water molecule almost 0.3 nm.

On a nanoscale, the properties of materials can be very different from those in bulk matter. Nanoscience can be defined as 'the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, in order to understand and exploit properties that differ significantly from those on a larger scale' [1]. Nanoscience is not really a new field, but a different way of looking at all fields. Its development will require the expertise of all scientists – from engineers to ecologists.

In simple terms, Nanotechnology can be defined as the 'design, engineering, characterization, production and application of structures, devices and systems by controlling shape and size on a nanometer scale'. A concise definition is given by the US National Nanotechnology Initiative: 'Nanotechnology is concerned with materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes due to their nanoscale size. The goal is to exploit these properties by gaining control of structures and devices at atomic, molecular and supramolecular levels and to learn to efficiently manufacture and use these devices' (EPA, 2009). This term can be applied to many areas of research and development – from medicine to manufacturing, to renewable energy, transport, computing, and even to textiles and cosmetics.

It can be difficult to think of and imagine exactly the world of atoms and molecules to get a greater understanding of how it will affect our lives and the everyday objects around us, but the areas where nanotechnologies are set to make a difference are expanding alongside the challenges they pose to society. Challenges in nanotechnologies can be presented in their hierarchical priorities (Fig.1).

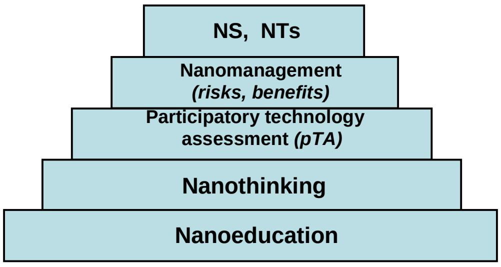

Figure 1. Nanochallenges hierarchy
(Lobanova-Shunina, Shunin, 2010)

Nanochallenges comprise such basic areas as *nanoeducation, nanothinking, participatory technology assessment (pTA), and nanomanagement (incorporating risks and benefits).*

Already today, many novel multifunctional nanomaterials, advanced nanodevices, new nano-based products and processes are designed and developed by team efforts of materials scientists working with chemists, biologists, physicists, information technology experts, and engineers. Therefore, the appropriate education, which produces young top-notch scientists, is a big concern. It is thus apparent that we need to create new types of universities, which have *'departments without walls'*.

2. The valuable contribution of nanoeducation to citizenship education

During the past 10 years, we have seeded many ideas into the global consciousness to stimulate preparing our students for their future. The world is changing but our education matrix remains in the Industrial version of reality. We are not even close to understanding, nor preparing our students for these major changes they will face in the next few decades. Nanoeducation **-** is the new foundation for the integration of all disciplines for the next generation to expand our student's knowledge base and prepare them for a very different future in a global society enhanced by all of the integrated science research now in process.

The contribution of nanoeducation courses to the development of the student's identity as a citizen is reflected in the purpose of the courses. The main objectives are to explore the nanotechnology potential benefits and possible risks for human health, safety and security, and the environment; to work internationally with fellow citizens to identify common values and institutions that will protect these values and to make them active.

To fuel students' reflections and allow them to cultivate their own citizenship identity, nanoeducation acts as a compass to help them position themselves within the whole of humanity. It is up to them to decide what kind of human being they want to be today, in their own immediate environment. Nanoeducation envisions developing *intellectual identity* in our students.

From this standpoint, students can establish with others a meaningful, fulfilling, and humane relationship. Such activities as creating a forum, for instance, where students can pursue their reflections and discussions with colleagues, as social players and not as mere spectators to discussions about nanotechnology realities of which they know little or nothing are a good measure of the contribution that nanoeducation courses bring to the development of citizenship awareness among students.

Many companies throughout Europe and the world report problems in recruiting the types of graduates they need, as many graduates lack the skills to work in a modern economy. For Europe to continue to compete alongside prestigious international institutions and programmes on nanomaterials, it is important to create educational institutions which would provide a top-level education and the relevant skills mix and would cover education, training, sciences and technologies for research and have strong involvement by European industry. The elements for such a high level education are:

- multi-disciplinary skills;
- top expertise in nanomaterials science and engineering;
- literacy in complementary fields (physics, chemistry, biology);
- exposure to advanced research projects;
- literacy in key technological aspects; exposure to real technological problems;
- basic knowledge in social sciences, culture, management, ethics, foreign languages;
- literacy in neighbouring disciplines: international business, law, IT, etc;
- interlinkages between education, research and industrial innovation: students will be ready for what research and development will provide;
- sharing of post-docs, Masters and PhD students to foster the mobility of permanent researchers and professors between different institutions to create 'team spirit'.

Companies, universities, governments, research organizations and technical societies must all strive to define their roles in this partnership. The 'output' will be graduates with a new way of thinking, skillful manipulators, synthesizers and creators of new knowledge excellently equipped to solve future complex problems and to work collaboratively.

The option offered by a new era of emerging technologies to all of us on the planet today can be spelled out in the words: 'nanoeducation can be considered a privileged discipline for supporting the development of responsible citizenship in the 21st century technologically empowered global society.'

3. Nanothinking as an educational concept of the 21st century

Data saturation that accompanies the 'new technologies age' has fostered an ever-increasing interdependency between people. The pace of expected adaptation is accelerated to a pace that exceeds individuals' abilities to accommodate. Being on the receiving end of technologies deluge serves to undermine people's confidence and sense of personal responsibility giving rise to the sense of helplessness that many people feel as the world enters the 'age of interdependency'.

Nanothinking can serve as the antidote to the sense of helplessness since it is a concept for seeing the 'structures' that underlie complex processes, for a much better understanding how our organism works, and for discerning how to foster health, safety and the surrounding environment. Our life is reduced due to ignorance and neglect of the elementary things concerning our health. If we do not understand ourselves, we will not be able to change our life for the better.

Nanothinking is a comprehensive systems thinking which offers a language that begins by restructuring the way how we think. It is a dynamic concept where practitioners continually engage in a process of 'seeing wholes' – a perspective that pays attention to the interrelationships and patterns of influence between constituent parts to foster the dissolution of compartmentalization of science and the corresponding compartmentalization of the mind.

Contemporary top-level education envisions causing students think systemically – integrating not only macro-, micro-, but also the nano scale. Nanothinking can be defined as '*visualizing matter, structures and processes at the nanoscale.*' Nanothinking can be viewed as *the understanding of nanophenomena within the context of a larger whole.* To *think nanoscalely* – means to put things into a nanoscale context and to establish the nature of their relationships within larger contexts.

Nanoscientists are now enthusiastically examining how the 'living world works' in order to find solutions to long-standing problems in the 'non-living world'. The way marine organisms build 'strength' into their shells or insects create the most amazing structures has lessons in how to engineer lightweight, tough materials for vehicles and other applications, or to improve the design and create even better structures for buildings and the environment. The way a leaf photosynthesizes can lead to techniques for efficiently generating, converting and storing renewable energy. Even how a nettle delivers its sting can suggest better vaccination techniques.

Natural systems provide us with solutions, but solutions are usually package solutions with concepts strongly interconnected one with the other. The problem is that too much of our thinking today in business – is poor business based on poor competence. We have one knowledge and we have one market. The time has come to re-think the system. And if we are prepared to re-think (probably due to the crisis) the business world, we will be able to re-think how to put innovative structures and systems into the production process. Education in this highly technological global economy has to play a double role. First, it has to provide a top-level, systemic, multidisciplinary education to graduates able to think innovatively and creatively. Secondly, it needs to educate the general public, thus, shaping citizens' consciousness.

Citizen thinking can be formed and improved through sustained and carefully crafted dialogue, which has to be integrated into educational communication practice. Educational communication has to contribute to developing a new way of thinking – the systemic thinking, with the main strategy – 'how to think' rather than 'what to think'. It is the privilege of a liberal university not to give the right answers to students but to put the right questions.

Educational communication, as human communication in general, can be defined (according to a German sociologist Niklas Luhman) in terms of interactive construction of meaning/thinking (Luhman, 2000). Language, as the main method of communication, shapes our way of thinking and, consequently, our feeling and acting.

Anthony Giddens, a British sociologist, points out that people are always to some extent knowledgeable about what they are doing. Because people are reflexive and monitor the ongoing flow of information, activities, and conditions, they adapt their ways of thinking/actions to their evolving understanding (Figure 2). As a result, *knowledge changes human ways of thinking/activities, thus, shaping our consciousness*. Language, in this respect, can act as a constraint on action/way of thinking, but at the same time, it also enables action by providing common frames of mutual understanding (Lobanova and Shunin, 2009).

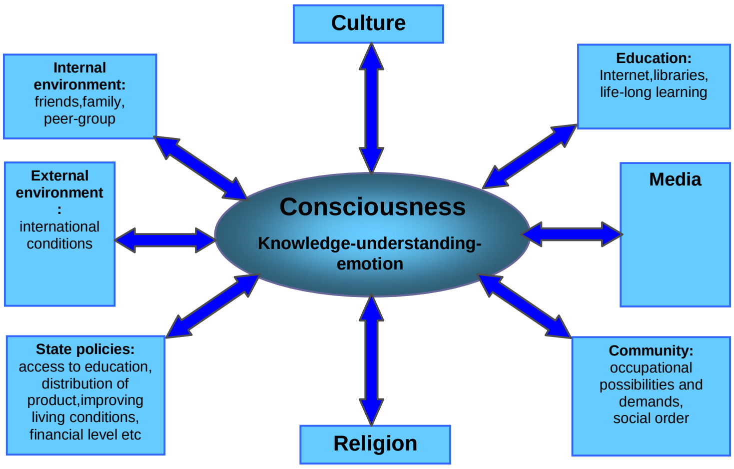

Figure 2. Shaping public consciousness. (Lobanova-Shunina, Shunin, 2010)

Consciousness is not inherited or static. It rather becomes a reflective project - an endeavour, which we continuously work out and reflect on. It is not a set of observable characteristics of a moment, but becomes an account of a person's life.

The development of a new way of thinking envisions bringing the practice of participatory technology assessment (pTA) into alignment with the realities of the 21st century technology – to create a 21st century educational model.

4. Citizen participative technology assessment (pTA) - a way of developing scientific citizenship

The ability to create novel biological organisms, manipulate matter at an atomic scale, or intervene significantly (and possibly irreversibly) in the earth's climate system raises a host of ethical, social, legal and environmental questions that will require broad public discourse and debate.

As nanotechnology has emerged from the laboratory into industrial manufacture and commercial distribution, the potential for human and environmental exposure, and hence risk, has become both reality and priority. Scientists and researchers engaged in nanoscience and nanotechnology research and development constitute a relatively small group compared to the general public. However, the outcomes of their work – innovative materials, systems, devices and technologies have a strong impact on the life of every citizen and the whole human society.

The research into health, safety and the environmental implications of nanotechnology lacks strategic direction and coordination. As a result, researchers are unsure about how to work safely with new nanomaterials, nano-businesses are uncertain about how to develop safe products, and public confidence in the emerging applications is in danger of being undermined.

Nanotechnology presents both an unprecedented challenge and unparalleled opportunity for risk management. Existing risk management principles are inadequate, given pervasive uncertainties about risks, benefits and future directions of this rapidly evolving set of technologies. The health implications of nanoparticles are unknown, the ramifications may be profound, and only a lengthy and extensive research effort can assess the safety implications with any certainty.

In light of these developments, it is important that the relations between science, technology and society be given proper attention in the education of citizens. Citizenship is about taking an active part in society. It is about ensuring that everyone has the knowledge and skills to *understand*, *engage with* and *challenge* the main pillars of our democratic society - *politics*, the *economy* and the *law*. Democracies need active, informed and responsible citizens; citizens who are willing and able to take responsibility for themselves and their communities and contribute to the wellbeing and safety processes.

However, citizenship capacities do not develop unaided. They have to be learnt. If citizens are to become genuinely involved in public life and affairs, a more explicit approach to citizenship education and involvement is required to deal responsibly with new technologies.

In the first place, citizen civil rights include the ensuring of peoples' physical integrity and safety (as the condition of being protected against physical, social, financial, political, emotional, occupational, psychological, educational or other types or consequences of threats).

Technology assessment (TA) is a practice intended to enhance societal understanding of the broad implications of science and technology. This creates the possibility for citizens of the world to influence constructively technology developments to ensure better outcomes. Participatory technology assessment (pTA) enables the general public/laypeople, who are otherwise minimally represented in the politics of science and technology, to develop and express informed judgments concerning complex topics, as well as, to make informed choices.

Since applications of nanotechnology will quickly penetrate all sectors of life and affect our social, economical, ethical and ecological activities, citizens' acceptance is compulsory for further developments in the field of nanotechnology and its applications. Consequently, it is of the utmost importance to educate citizens, and to disseminate the results of nanotechnology development in an accurate and open way so that the general public will eventually transform their way of thinking to accept nanotechnology. In this endeavour, educational institutions have a pivotal role in developing pTA practices by:

- educating citizens (pupils, students) about science and technology;
- informing the public about the benefits and risks of nanomaterials and nanoproducts;
- evaluating, minimising, and eliminating risks associated with the manufacturing and use of nanomaterials and nanotechnology enabled products (risk assessment);
- exchanging with public authorities for the risk management of nanotechnologies.

In the process, pTA deepens the social and ethical analysis of technology, complementing the expert-analytic and stakeholder-advised approaches. The Internet and interactive TV capabilities can help pTA be more effective and cost-efficient and would also align with the policy-makers' initiatives to make them more transparent, accessible and responsive to citizens' concerns.

5. To move with the times and keep abreast of the fundamental knowledge of the day

With the aforementioned in mind, we launched a pilot study at Information Systems Management Institute (Riga, Latvia) in different groups of students comprising Information Technologies, Management, Tourism, and Design departments as well as international students enrolled in ISMA on the ERASMUS student exchange programme.

We have undertaken a set of researches into the nature of students' intellectual potential development in order to elicit their general knowledge of some basic scientific notions and their understanding of the utilitarian value of some scientific phenomena. The study envisioned providing the necessary knowledge, understanding and support to our students to be successfully introduced to the technologically empowered environment of today's life, to adjust and adapt in it.

The purpose of the pilot study was primarily to work with the delivery of the questionnaires and interview questions to determine what was required to elicit the quantity and quality of data needed to respond powerfully to the research question. As a result of four pilot undertakings – a fluid conversation with students, an interview, a questionnaire with a feedback analysis – a level of intimacy and trust was created that supported the gathering of quantity and quality data (Fig. 3).

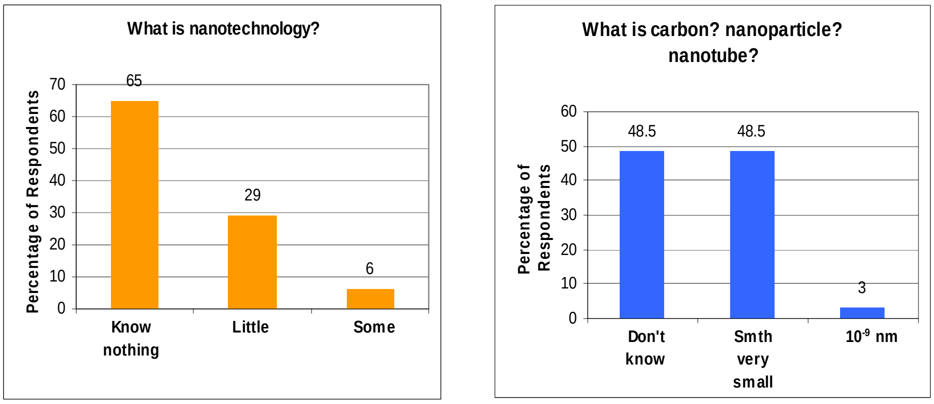

Figure 3. Latvian student awareness of nanotechnologies (*ISMU students*)

The results of the study make us conclude that students' general knowledge of basic disciplines is rather restricted, sometimes rather obscure or fluid. What is more discouraging, the research has established that students do not possess the systemic vision of the sciences and the world. Their knowledge is compartmentalized – they are unable to relate physics to chemistry, to biology, etc. Hence is their low level of awareness of many innovations in science, and especially, in developments in the field of nanotechnology and its applications. This is mainly due to the inability to imagine the world at the nanoscale level. Hence is the fragile confidence in technological innovation and regulatory systems.

There might be objective and subjective reasons for the situation observed. Most higher education teachers feel that the knowledge students gain at secondary school is not sufficient for a higher education institution. In particular, a Latvian scientist – professor of Latvian University Dmitry Babarykin – relates it to the decrease of general level of secondary education. According to Babarykin, since chemistry and biology (disciplines about life) were excluded from obligatory subjects at school in Latvia, people have become too credulous, unable to evaluate independently the expediency of many important things influencing their lives. But most importantly, our educational programmes are structured in the way that perpetuates the myth that knowledge exists in separate compartments, as if there were no relationship between physics, chemistry, biology; between language and literature, and art, and history, and in so doing, encourages a similar compartmentalization of the mind. At the same time, the main problem area mentioned concerns the link between theoretical knowledge and students' envisioning their utilitarian value.

To fuels students' interest as citizens so that they would be curious about the state of current knowledge and new technologies regardless of their major, a project was initiated as an educational supplement featuring the reflections of the general public on nanotechnologies. Our mission had a focus on preparing students to follow the evolution of knowledge and technologies, to be active citizens today and speak knowingly on questions dealing with quality of life on earth and within society.

A group of first-year students (concurrently with a general nanoeducation course) investigated public concerns about nanotechnology in their project work (Fig. 4).

Normally, survey-based research on the public understanding of science and technologies is performed by social scientists, who are sometimes – and sometimes not – well-informed about the field of science and technical activities in question, but who are not themselves knowledge producers within the field.

The nanotechnology students' surveys represent a direct link between producers and (potential) users of nano-knowledge. Another result of their learning process was the development of a strong commitment to engaging in dialogue with lay citizens. By fostering their hybrid imagination, the students developed a kind of 'scientific citizenship', which simultaneously embraces scientific competence and social responsibility.

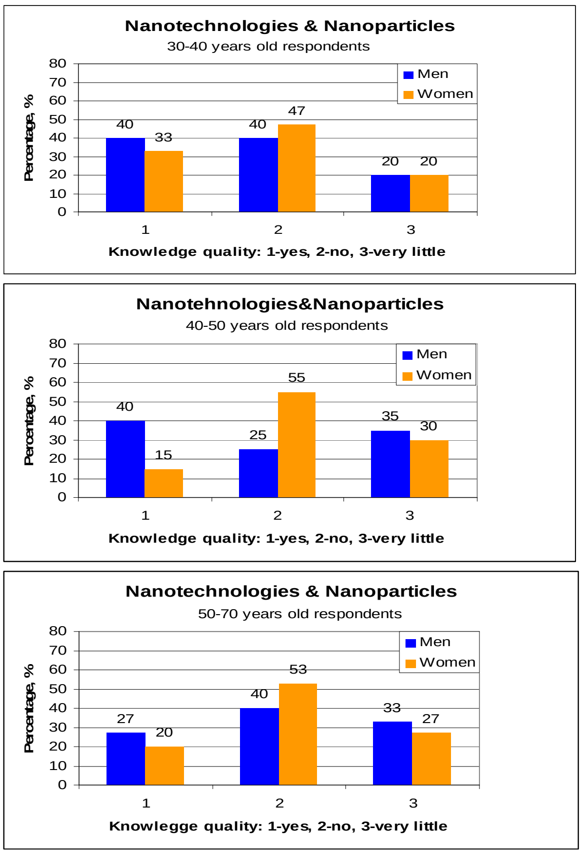

Figure 4. Latvian citizen awareness of nanotechnologies in various age groups

Conclusion

Problems are international and exist beyond our times. To speak out is to show commitment to our environment and to our colleagues, to begin to work towards peace, cooperation, the development of human activities, and for good and healthy life for our generation and the ones to follow.

Learning to move with the times, understanding the fundamental knowledge of our day, learning how to share in the governance of our society, and showing solidarity - these are the components of learning how to live together as humans as well as the broad guidelines in citizenship education.

The basis of any reflection whether personal or social, rests on an enlightened and critical intellect. Given its ubiquitous nature, nanotechnology is an essential component of citizenship education. It motivates the young adult to shape his thought process, to favour opportunities that refine his critical judgment and allow him to look upon the society of which he is a full member with a clear and constructive eye. He will then be ready to play his role as a citizen and contribute to the ongoing growth and wellbeing of his community.

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