This paper is taken from

Creating Communities: Local, National and Global
Selected papers from the fourteenth Conference of the Children's Identity and Citizenship in Europe Academic Network

London: CiCe 2012

edited by Peter Cunningham and Nathan Fretwell, published in London by CiCe,
ISBN 978-1-907675-19-5

If this paper is quoted or referred to it must always be acknowledged as
Lobanova-Shunina, T. & Shunin, Y. (2012) 'Nanoeducation for developing responsible scientific citizenship and creating a sustainable intellectual global community', in P. Cunningham & N. Fretwell (eds.) *Creating Communities: Local, National and Global*. London: CiCe, pp. 316 - 326.

CiCe
Institute for Policy Studies in Education
London Metropolitan University
166 – 220 Holloway Road
London N7 8DB
UK

This project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Acknowledgements:

This is taken from the book that is a selection of papers given at the annual CiCe Conference indicated. The CiCe Steering Group and the editor would like to thank

- All those who contributed to the Conference
- The CiCe administrative team at London Metropolitan University
- London Metropolitan University, for financial and other support for the programme, conference and publication
- The Lifelong Learning Programme and the personnel of the Education and Culture DG of the European Commission for their support and encouragement.

Nanoeducation for developing responsible scientific citizenship and creating a sustainable intellectual global community

Tamara Lobanova-Shunina and Yuri Shunin
Information Systems Management University (Latvia)

Abstract

We live in the twenty-first century where change occurs very quickly and living in such a fast-changing world we must decide to live with a sense of universal responsibility, identifying ourselves with the whole global community as well as with our local communities. We are at the same time citizens of different nations and of one world in which the local and global are intertwined. 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 human beings as well as the broad guidelines for responsible scientific citizenship education.

Keywords*: Nanoeducation, responsible scientific citizenship, intellectual society, sustainable democratic community*

Modern technology requires an educated workforce and hence there is imperative for an educated population. The needs of new emerging technologies and a beneficial state of society are compatible in this case. There is no monolithic thing called technology rather there are various technologies that converge or compete to fit into what can be called an ecosystem of technological and societal arrangements. Societal and technological arrangements co-evolve. This co-evolution happens most favourably in an educated, intellectual, and affluent society that is tolerant of change and divergent views. By fostering an educated, intellectual society it creates conditions that foster responsible moral and social behaviour of the individual and contributes to shaping intellectual mankind (Langdon, 2010).

1. Higher education as a means for social change: who needs nanoeducation?

Important questions have been raised about the technology's potential economic, social, and environmental implications by prominent technology leaders, nanotechnology boosters, science fiction authors, policy officials, and environmental organizations. But there is very little knowledge in wider European society about what nanotechnologies are and what impact they might have on how we live. Many experts acknowledge that uncertainties prevail about this.

Innovative technologies based on multidisciplinary research provide an abundance of potential applications. While advocates preach a revolution, e.g. in chemical production methods, medicine, material science and energy systems, critics warn about unknown side-effects, e.g. allergies, and deliberate misuse of the technological solutions developed. Higher education has to be at the heart of these processes, ensuring accessible information that will allow people to better understand what nanotechnology is, how it will be applied, and its implications for society (Lobanova-Shunina, Shunin, 2011a).

Consciously or unconsciously, the term ‘nanotechnologies’ is firmly entering the life of every citizen of the global community designating both relatively simple nanomaterials and goods such as plastic bags or containers, and very complex technologies that are supposed to change radically the future of mankind, such as prosthetic implants that are controlled by the brain and move, feel, and have the sense of touch like real ones; or invisible brain implants that would enhance human memory storing information equal to several big libraries, altering mood and controlling artificial limbs. In fact, nanotechnologies include an extremely wide range of potential applications comprising food and beverages, dental fillers, toothpaste, optics and electronics, clothing, wound dressing, sporting goods, dietary supplements, cosmetics, and many others.

The central question on nanoeducation is ‘Do we need nanoeducation?’ To answer this question, we should first find out who needs nanoeducation? Who has expressed the need for nanoeducation in the past? What is the interest in nanoeducation from the people who have expressed the need? What kind of education is needed (expertise, skills, level)? For what kind of jobs are knowledge and skills of nanotechnology needed? (Lobanova-Shunina, Shunin, 2011b).

Nanotechnology has shaken the world and the advanced countries are investing billions of dollars for its R&D and industrial applications. For example, USA cumulative investments in nanotechnology-related research since 2001 now total over 16.5 billion dollars (environmental, health, and safety research since 2005 now total nearly $575 million; education and research on ethical, legal, and other societal dimensions of nanotechnology since 2005 total more than $390 million) (NNI, 2012). Similar amounts are being spent on nanotechnology by Japan, Russia, China and European Union. Nanotechnology has therefore been taken up in these countries as an important national requirement.

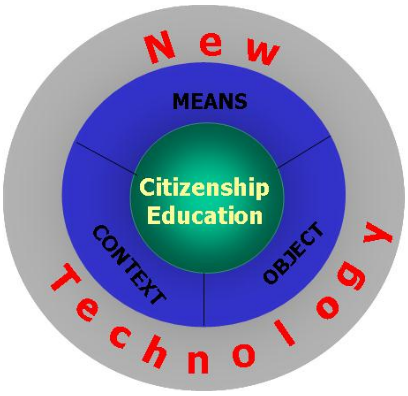
The National Science Foundation (NSF) has estimated that by 2015 the world will require about 2.000.000 multidisciplinary trained nano-technologists, including Europe with about 3-400,000 nano-specialists.

The European Commission highlights the need to promote the interdisciplinary education and training together with a strong entrepreneurial mindset. It is emphasized that the need for nanotechnologists will not only be confined to the industrial and R & D sectors but will be needed practically in all spheres of life. Experts have estimated that marketing of nano-based industrial products will have risen to some 2-3 trillion dollars by 2015, and nanotechnology is going to dominate the socio-economic life of the world for the next 40-50 years.

Since Nanotechnology is starting to play an extremely important role in the socio-economic development of all countries for the foreseeable future, it is imperative for higher education that emphasis be placed on producing a properly educated, qualified and trained specialists that can cater for the future of the society they live in.

To create a sustainable, democratic, technologically empowered and intellectual global community, citizenship must, in one way or another, come to terms with new emerging technologies and identify the paramount place that new technologies have taken in the society. Therefore, the presence of new technologies - as *means*, *object,* and *context* - in the sphere of contemporary higher education is undeniable (see Figure 1). Responsible citizenship is based on understanding of advantages and threats of new technologies.

Figure 1. **New technology as means, object, and context, of contemporary higher education**



2. Quality education for intellectual youth and sustainable future

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 responsible citizenship education on the way to intellectual society. 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. S/he will then be ready to play his role as a knowledgeable citizen and contribute to the on-going intellectual growth and wellbeing of his/her community.

Sustainability is defined as a long-term maintenance of responsibility, which has environmental, economic and social dimensions and encompasses the concept of responsible management. In its turn, responsible management rests on knowledge and understanding of new technologies and scientific advancements fostering the societal development.

Unfortunately, our previous research on Nanoeducation and Nanothinking has revealed a dramatically low level of basic scientific knowledge and nanotechnology utilitarian value in Latvian students. The research results stimulated the educational component redesign at Information Systems Management University (ISMA), Riga, Latvia. Our mission had a focus on introducing a general nanoeducation course into the curriculum in 2011 to eliminate gaps in scientific knowledge of our students and to foster an active approach to *Quality Education for Sustainable Future* (QESF). The general ambition has been to add some non-technical instruction into the curriculum in a way that fits the ISMA Systemic educational model of problem- and project-based learning.

The course is built around active learning methods to promote an active discussion-based approach to developing responsible scientific citizenship and to offer an opportunity for students from a wide range of disciplines, including the natural and social sciences, humanities, business, information technologies, and tourism to learn about nanoscience and nanotechnology, to explore these questions, and to reflect on the place of technology in the spheres of their major and in the global society.

We believe that effective and successful development of responsible scientific citizenship depends on a well-balanced integration of the three components: 1) new emerging technologies education, 2) citizenship education, and 3) the humanities education fostering social responsibility.

At the initial stage (the receiving and knowledge levels) the three domains can operate with near independence. But as a person reaches the stage of a high level of techno-scientific proficiency combined with socio-cultural and ethical knowledge (the integration and evaluation levels) the overlap area approaches totality. Scientific knowledge educates citizens about their powers and responsibilities. In this model, the citizen is not a mere consumer of scientific knowledge, but a person whose voice and opinions are heard and valued. And if the process is strategically targeted, we can view education as a contribution to a scientifically literate, intellectual society (local-European-global) where young generations are able to take responsibility for its sustainable development.

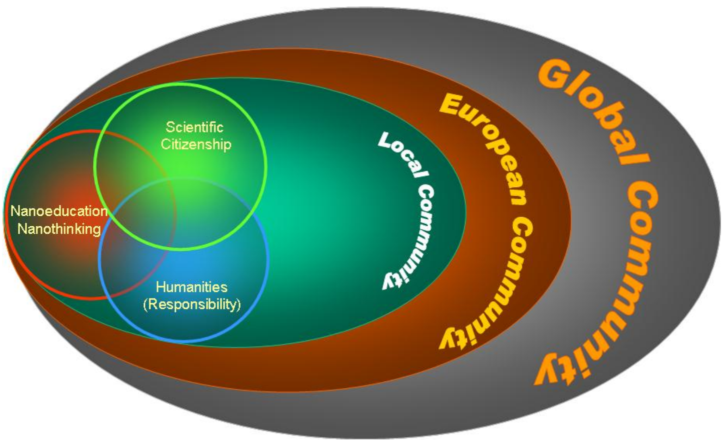


Figure 2. Responsible scientific citizenship development based on interdisciplinarity

The QESF course exploits the Systemic approach to the educational process and aims at developing the students' systems thinking, critical thinking, and contextual thinking (learning transfer), as well as organization and communication skills, problem-solving and decision-making abilities, thus, contributing to the integrated skills development.

From the Systemic perspective, an individual, as a social being, educates, self-organizes, and develops his personality through interaction and communication. Inferred from this is the vision that personality is a systemic quality including both biological factors and social formations. Therefore, the Systemic approach to educational process contributes to personality development engaging both biological and social aspects. This process is purposefully organized. From this point of view the Systemic approach is considered as personality-directed.

According to Lev Vygotsky (1991), education can only then be useful if it comes before development. Preceding development, education rests on its achievements, finds the resources for further realization of educational perspectives. Hence is the dynamism of personality development in the educational process. This major principle formulated by Vygotsky, means that through interaction and communicative activities, psychic functions (thinking, memory, knowledge accommodation) are formed, as well as social skills, ethic norms, values perception, and self-awareness are developed. From this perspective, the Systemic approach can be viewed as an activity-based approach.

The Systemic education and development promote self-education and self-development, contributing to life-long learning. Inferred from this, we can say that the Systemic approach can be viewed as holistic, leading to the global personality development.

QESF is not a mathematical or technical course. In fact, we spend most of our time on the humanities side of the world, but students get the general knowledge of nanoscience, nanotechnologies and their implications in the society as a result of integration of the humanities with technosciences. The course places emphasis on humanitarian applications of new technologies by focusing on the role of technologies in tackling society's grand challenges such as safety, health and environment.

Integration of the humanities with technosciences, envisages the development of scientific competence, providing all the citizens with the abilities to assess new technological and scientific developments, and, thus, be engaged in educated problem-solving forums and responsible decision-making legislatures. The course is to be guided by teams of teachers from a diverse array of disciplines. Science and technology teachers will have to learn humanities and social sciences. Humanities and social science teachers will have to learn sciences and technologies, promoting interdisciplinarity.

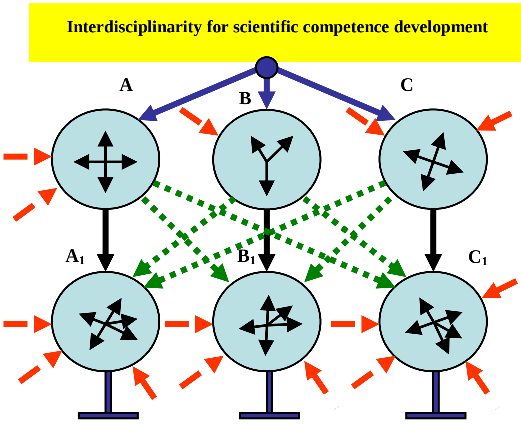


Figure 3. Scientific competence development under the systemic approach

In the interactive process of interdisciplinary activities, new abilities appear - emergent abilities (Lobanova-Shunina, Shunin, 2009) that reinforce scientific competence and contribute to its development (in Figure 3 - arrows inside the circles). It is necessary to emphasize that the essence of mechanisms showing the emergence of new abilities can be demonstrated only by means of models created within the framework of the systemic approach as these 'new' properties have to be additive.

To a large extent, the course is about connecting disparate questions, concepts, facts, and ideas, and then raising new questions – it is a vital process in this approach to nanothinking because it is a formal way of integrating ideas and communicating.

3. From intellectual youth to intellectual society

In our educational approach we support the idea that instruction should not be separated from practical context and this is the concept that should be maintained as the main classroom philosophy, since skills have not only to be learned, they have to be experienced through the practice of implementation.

Therefore, concurrently with the general nanoeducation course, the quadruple-approach nanoproject *'From Intellectual Youth to Intellectual Society'* (FIYIS) has been launched that organizes conferences for students as well as the university teachers and the general public. Initiated by several professors from Latvia, Israel, and Russia, this project has been designed as an educational supplement featuring the reflections of reputed scientists who propose basic ideas for intellectual growth, while focusing on today's most pressing problems. Among these are Arnold Kiv, Yuri Shunin, Paul Dyachkov, to name a few.

The teaching objectives of the nanoproject FIYIS envision a broad-based integration of technosciences and the humanities at the university level, so that both future technoscientists and humanoscientists develop a common understanding and, possibly, even a common language to deal with complex social, ethical, legal and political questions arising from the development of nanotechnology and from its convergence with other techno-scientific developments, the answers to which are to be found on the counterbalance of technologies and humanities. Without that counterbalance, society risks scientists without conscience, technicians without taste, and businessmen without responsibility.

The learning context of the NanoProject is subdivided into four basic levels, comprising Ecological/Environmental Level, Health and Medical Level, Consumer Goods Level, and Information Communication Technologies Level. FIYIS – is an integrated skills project that presupposes the engagement of all students into the research of the Nano-world, irrespective of their major.

Thus, the 1st year students tackle the 1st Level tasks: through simulations, role plays, discussions, and negotiations they develop their communication and social skills. As a deliverable of the project, they might make a nanoproduct presentation: home-related nanoproducts. The 2nd year students learn to select, process and analyse scientific information dealing with the 2nd Level tasks, thus, developing research-based learning skills, and problem-solving skills. The 3rd year students acquire all the aforementioned strategies and skills and go a step further – the tasks of the 3rd Level aim at developing not only scientific competence but also at a global personality development of the student through the experience of learning (attitudinal change – to nanoproducts, to each other, and to the process of learning – i.e. motivation, student awareness, and social scientific responsibility). The goal is to produce a pamphlet on key nanotechnologies and nanogoods circa 2015 that may have value to producers, managers and consumers, as well as to future iterations of the class.

There is a special merit in the 3rd Level tasks – that is a high degree of task authenticity, globality, integration with other subjects and involvement of all the aspects of the individual's personality, previous experience and knowledge. Nanothinking and creativity are the factors that link all these elements.

The most common approach, however, as at many other universities, seeks to provide the first-year students with an understanding of the commercial conditions in their subject area, and the project work often involves a market analysis of the particular technical or scientific product that the students are learning how to make.

The second approach provides what might be termed an academic understanding of contextual knowledge. The course provides an introduction to the philosophy of science and technology, and in the project work, the second-year students are encouraged to use these philosophical ideas to consider the ways in which knowledge is produced, or constructed, within their fields of major.

The third type, which we have developed in the new educational program in nanotechnology, can be termed a socio-cultural approach to contextual knowledge. In our lectures we have introduced the local and the ERASMUS students to the cultural history of science and technology and, in their project work, we have advised the students as to how they might address, and, at best, assess the cultural and ethical implications of the emerging technologies in their fields of major. The approach is valuable since it tends to regard issues of social responsibility and of what we have come to characterize as scientific citizenship.

Normally, the project lasts for one semester, although it can be prolonged for the whole academic year, depending on the tasks and goals. The necessary information is gathered from different sources – course books, extracurricular books, the web, site visits, and interviews with specialists and experts. Students should be encouraged to think of projects as not requiring standard, back-of-the-book answers; rather, different teams undertaking the same project could arrive at different conclusions and deliverables.

A brief pre-assessment is given in the first week of class and two more detailed assessments are given in the last week of class. Several feedback surveys are made during the semester. The assessments and surveys show that the students have found the course valuable and that many of the goals in the syllabus have been met.
Continuous assessment has to be used to gain information about the effectiveness of class discussions and enhancement of students' understanding of the interaction between nanotechnology, individual, and society.

At the end of a project, every student must submit a statement of personal growth - what he/she expected at the initial stages of the project, and what has actually been learnt by the end of the project. The statement of personal growth may incorporate nontraditional objectives, containing reflections on:

- the relevance of the project to the community, city, nation, Europe or the world;
- suggestions for follow-up projects and other activities.

Nanoeducation challenges all students to broaden their horizons and gives them ways of acquiring knowledge of things that shape intellectual society. It fuels their interest as citizens so that they would be curious about the state of current knowledge, regardless of their major. It prepares them to follow the evolution of knowledge and technologies, to be active responsible citizens today and speak knowingly on questions dealing with quality of life within their local communities and the global society.

Not only would the practice of open discussion, problem-solving, decision-making, and statements of personal growth encourage healthy introspection, it would also anchor the scientific and technical disciplines with humanities and social sciences. This is especially important because the exceptional synergy of nanotechnology with other disciplines creates significant social, legal, ethical and political issues that can be effectively resolved and outspoken only by the intellectual citizenry of an intellectual community.

Finally, a gap analysis can be implemented to provide the best way of strategic assessment and planning.

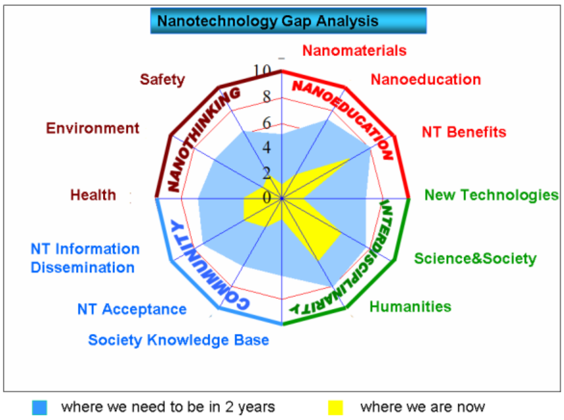


Figure 4. Gap analysis of knowledge

It allows comparing two series: 1) where we are now and 2) where we want to be in some time in the future, making it easy to identify the gaps in knowledge that need to be closed. For each area giving us a complete picture of the situation we ask two questions:

- Where are we now?
- Where do we need to be in 13 weeks' time?

Actually, we have to answer three questions:

- How are we doing?
- How should we be doing?
- How much do we need to improve? (the gap)

We can then quickly identify where the gaps are and whether things need to improve.

Conclusion

There is now a growing consensus that the global society of the 21st century is on a way that is not sustainable. The contemporary forms of political economy are failing to conserve ecological resources and services, to guarantee economic stability, to maintain cultural diversity, to ensure environmental security, and to protect people's physical and mental health. We face corresponding crises of ecological, economic, social, cultural and personal sustainability.

Nanotechnology is expected to radically alter the human condition within a short span of time, probably not exceeding two decades. Human cultures, however, do not change at the same rapid pace. Technoscientists as well as humanoscientists begin to ponder and predict the parameters of possible social, environmental, ethical and legal changes to emerge in the first two decades of the new millennium. At the same time, the preparation of future leaders and engaged citizenry to cope with unpredicted changes has obviously to begin at schools and universities.

Most of today's higher educational institutions are awash in technology but the outcomes for students remain little changed from 20 years ago. The problems are not in our technology but in our universities. The reasons are due to our attitudes toward education - how we underfund it, mismanage it, politicize it and disempower it in our culture. We have to dare shake education out of its two-centuries-old inaction/inertia. New technologies and education are inseparable. Involving the general public into decision making is a key element of social learning for sustainability.

Education for sustainable development should develop knowledge and understanding of the social, economic and environmental dimensions. Addressing the social dimension clearly involves citizenship education based on knowledge and understanding of the new technologies fostering the societal development. The European Union is stimulating the development of nanoscience education in universities to address complex issues and to solve multidisciplinary problems, in general.

From a practical stance, nanotechnology is widely considered to be 'the next big thing' and is well worth learning more about in order to get a knowledgeable understanding of what is nanotechnology? Is it all hype? Is it dangerous? This essential knowledge will not be developed by chance, but by strategic, targeted teaching.

On another level, at the intersection of technology and society, there is a new angle to think of some timeless issues. Is nanotechnology good? What is progress? How much risk are we ready to take? Why should we care about the societal implications of nanotechnology? These are profoundly important questions the answers to which are to be found on the counterbalance of technologies and humanities. Without that counterbalance, society risks scientists without conscience, technicians without taste, and businessmen without responsibility.

Values reflect and shape the on-going social development. Understanding the impact of a new technology on society is vital to ensuring that development takes place in a responsible manner. Scientific knowledge is expected to play an important role in educating citizens about their powers and responsibilities. In this case, the citizen is not a mere consumer, but a person whose opinions are valued.

A democracy needs an educated citizenry. What does an educated citizenry in a technological age look like? To participate in a democracy influenced by technology not only do citizens need to know how to understand the multiple perspectives that they encounter, they need to feel an obligation to explore multiple perspectives to fully understand the society they live in and make informed decisions.

When we do not pay close attention to the decisions we make, when we fail to educate ourselves about the major issues of the day, when we choose not to make our voices and opinions heard, that is when citizenship and democracy breaks down.

A new interdisciplinary course, developed at ISMA, places an emphasis on humanitarian applications of new technologies by focusing on the role of nanotechnologies in tackling society’s grand challenges such as safety, health and environment. Our hypothesis is that this new approach to teaching about technologies will engage and inspire students who have typically been turned off by the traditional educational experience. Additionally, we believe that this course will better prepare a new generation of specialists to address major societal problems in the future maintaining at the same time an awareness of political, economic, ethical and social constraints on technologies.

References

Langdon, W. (2010) *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago: University of Chicago Press

Lobanova, T. & Shunin, Y. (2009) Language as a social behaviour: integration of language, communicative competence and identity development, in Ross, A. (ed) *Human Rights and Citizenship Educatio*n. London: CiCe, 306 – 312

Lobanova-Shunina, T., Shunin, Yu.N. (2011a) Nanothinking as an Essential Component of Scientific Competence and Social Responsibility in the 21st Century Society. *Computer Modelling and New Technologies* **15**, No.1, 58-68

Lobanova-Shunina, T., Shunin, Yu. (2011b) Nanothinking as a Concept of Citizenship Education for the 21st Century Europe, in P. Cunningham & N. Fretwell (eds) *Europe’s Future: citizenship in a changing world.* London: CiCe, 345-355

National Nanotechnology Initiative-NNI (2012) http://www.nano.gov/