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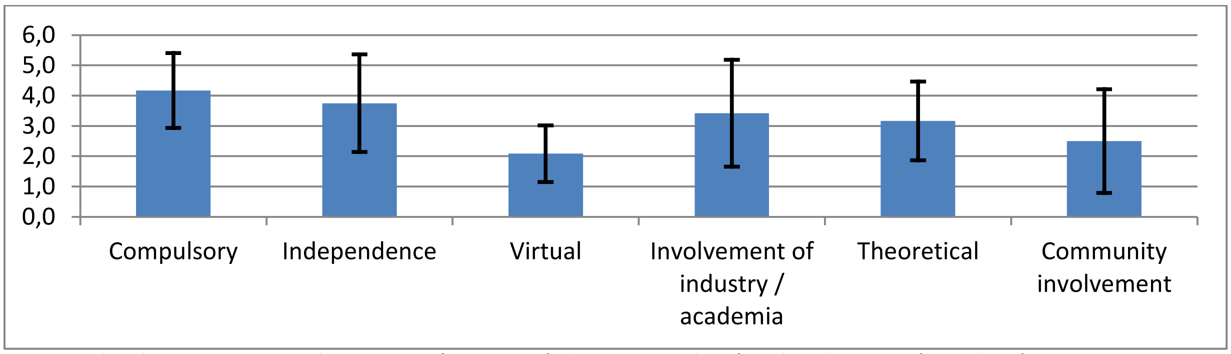
Executive Summary

This report summarizes in-depth research performed into 12 projects in the EC and associated countries, presenting the best practice on different scales, from an EC-initiated project implemented throughout Europe down to a local initiative at a single school. The geographical heterogeneity was taken into account to ensure the report's validity. Each project was examined and scored according to six parameters in order to outline and compare the various profiles, strengths and weaknesses. This report will serve as foundation for formal recommendations on the matter.



The chart examines each parameter's average (column, scored 1-5) and its deviation (error bars)

The projects shared similarity in three parameters: [1] most projects were compulsory; [2] all but three projects made use of a virtual platform; and [3] a high ratio of theoretical vs. hands-on pedagogical approach and practice. The projects greatly varied in the other three parameters: [1] the degree of independence i.e. is the project taught as part of an existing subject or as an independent subject; [2] the involvement of industry or academia; and [3] community involvement.

These results show that the main strength of a best practice project is being taught as a compulsory subject, albeit not necessarily one which is hands-on. These results has two meanings: [1] is that relying on voluntary attempts does not reach the audience of secondary school students and [2] that introducing hands-on activities to the classroom as a general practice has yet to be undertaken. Surprisingly, virtual platforms were not found to have been used very much and community involvement was generally scarce, as well. Virtual teaching methods could improve projects educationally, broaden the discourse and reinforce the reported benefits of community involvement while also addressing hard to reach audiences.

The projects greatly vary in terms of the independence of the subject and cooperation with industry and academia. This variance suggests that mutual learning could greatly contribute to promoting good practices to more scalable nanoeducational approaches.

Introduction

The present document constitutes Deliverable D3.1 in the framework of the NanoEIS project titled "*Nanotechnology education for industry and society*" (Project Acronym: NanoEIS; Contract No.: NMP4-SA-2012-319054).

This report has been prepared by ORT Israel and NUID UCD as part of activities performed within Work Package 3 "Assessment of EU education in nanotechnology" and more specifically T3.1 "High schools – assessment of nanotechnology education programmes within science subjects or as independent courses". The document aims to analyse the current integration of nanotechnology into secondary school curricula. It offers assessment of different approaches that will be compared. In future NanoEIS reports, in accordance with results of existing good practice examples, we will offer some recommendations on how to go from isolated examples of good practices to more scalable nanoeducational approaches. Analysis of best practice examples will lead to the identification of factors which can then enable success.

The Benefits of Teaching NST in Secondary Schools

As in any other report that is written as part of the NanoEIS project dealing with secondary schools, we would like to emphasize the benefits of learning NST at this early stage.

One of the main objectives of introducing NST to the secondary school system is to invite students to learn and discuss scientific knowledge of social interest relevant to the learning materials (among other things), so that students can critically evaluate what they read in newspapers or see on TV from a more objective perspective.

In 1902, Dewey already stressed that exposing students to new scientific and technological developments is fundamental to their learning progress and for promoting change. Accordingly, recent studies have found that nanotechnology attracts and increases students' motivation to study science (Blonder & Dinur 2011). The applications of nanotechnology have exemplified how modern research is transformed into useful applications and they have demonstrated the importance of science and technology in everyday life. Furthermore, Roco (2003) underscored the importance of education for the future development of nanotechnology and described the lack of emphasis on it as a bottleneck with regard to future development of the field.

As mentioned above, the following paper will analyse some best practices from different EU and associated countries where NST education has been implemented. The insights of this report will be used to write recommendations for the EU authorities regarding how to progress from isolated examples of good practice to more scalable nanoeducational approaches.

Methodology

This is a semi-qualitative report and by no means a quantitative one.

The initial selection of the programs in this report is based upon previous reports that have been submitted as part of the NanoEIS project:

- MS2: Selection of secondary school programs for in depth study – Submitted in May 2013
- D2.3 (WP2): Report on secondary school education – Submitted in July 2013

Based on our existing knowledge, acquired over the course of several years of working and researching NST pedagogy in secondary schools in the EU and associated countries, we propose a framework to categorize nanoeducation programs according to their initiator. The programs that are being analysed differ based on the following eight initiators: (1) the EC (European Commission); (2) national governments; (3) regional authorities; (4) national school systems; (5) industry; (6) academia; (7) science museums; and (8) school initiatives.

Ultimately we selected 12 programs that represent the best practice of teaching NST in secondary schools, providing at least one example for each initiator, after at least one of the following threshold requirements was reached:

- Programs that are **widely implemented** – In terms of the number of participants, the geographical area, etc.

- Comprehensiveness – How **rich and innovative** the program was in terms of content, new teaching methods, etc.
- **Involvement** of the community, industry and academia – Whether there was any collaboration with different stakeholders in the school's immediate surroundings.
- **Award** winners – Programs which were acknowledged through national or local awards.
- **Growing** program – Programs that grow every year, even if the initial phase has been concluded.

The main source of the data gathered for this report was a semi-structured in-depth interview with at least one key person for each program that was researched.

Additionally, an online questionnaire[1] was circulated among the teachers who were involved in the different programs. Finally, quantitative and other data was retrieved from official websites, as well as published or circulated reports on each program.

Review of Parameters

In order to construct insights regarding the nanotechnology educational programs, we examined them according to the parameters detailed below. The in-depth online questionnaires (see appendix) show that we examined additional parameters that were later abandoned either due to lack of sufficient data or to being deemed as extraneous to the program (i.e. not contributing to understanding the programs' success) such as gender ratio or the level of students' academic heterogeneity.

1. **Compulsory vs. voluntarily** – Whether the program was integrated into the formal school curriculum as part of regular school hours (making it compulsory), or participation was voluntary and it was regarded to be an extracurricular activity.
2. **Independent subject vs. integrated** – Whether the program was taught separately from the existing science courses, or it was integrated into chemistry, physics or biology courses.

[1] The questionnaire can be found in the apendix at the end of this document

3. **Virtual vs. frontal teaching** – The ratio of instruction through virtual, self-learning activities compared to classic frontal teaching, if applicable.
4. **Involvement of industry/academia** – As mentioned above, we checked whether there was any collaboration with these stakeholders which could influence the students' future educational and/or career decisions.
5. **Theoretical vs. hands-on** – The ratio between the content that involved theoretical teaching of NST and hands-on activities (i.e. lab experiments, excursions, role playing, debate events, etc.).
6. **Community involvement** – We referred to involvement of parents, local authorities, and the lay public in the school community.

Terminology

The secondary school systems in EU and associated countries differ significantly and this report had to take into account these variations. When examining the implementation of different curricula and special programs we referred solely to ninth grade and above (i.e. 14-18 year old students).

In this report we will refer to the general and interdisciplinary subject of **N**ano **S**cience and Nano-**T**echnology with the abbreviation **NST**. Another abbreviation used in this report is **STEM**, **S**cience, **T**echnology, **E**ngineering and **M**athematics.

Several projects discuss the **e**thical, po**l**itical and **s**ocial **a**spects, abbreviated as **ELSA**.

Best Practices of Nanoeducation at the Secondary School Level in the EU and Associated Countries

Over the past decade a few nanoeducation programs introduced the relatively new subject of NST to secondary schools in the EU and associated countries. In this report we examine 12 projects from different parts of the continent. After ranking them according to the eight-level initiator scale, we examined them according to the six parameters defined above (see Methodology).

The projects in this report where selected by being noticeable among the secondary education community and specifically the newly formed NST education community, to which the writers of this report belong.

To visualize the factors that influence the success of the examined programs, we summed up each program in a radar chart. The American Society for Quality defines a radar chart as: “A graph with multiple scales to report self-assessed knowledge or competence, often several points in time” (American Society for Quality, 2006). We created a chart for each program. In the report summary, we provide the whole picture in a single chart which is discussed as part of the conclusion. Most notable

1. EC-Funded Projects

For more than a decade the European Commission has been funding pan-European NST projects intended to promote NST in secondary schools. As part of those projects, some content was developed (in several languages), which was distributed via web portals and which continues to provide science teachers with content for their lesson plans.

Although not examined in this report, it is worthwhile to mention the Scientix project, which started in 2009 and has since promoted and supported a European-wide collaboration among STEM teachers, educational researchers, policymakers and other STEM education professionals. The project's portal offers a repository of teaching materials (including NST) in different languages.

1.1. Nanoyou

Website: http://nanoyou.eu/

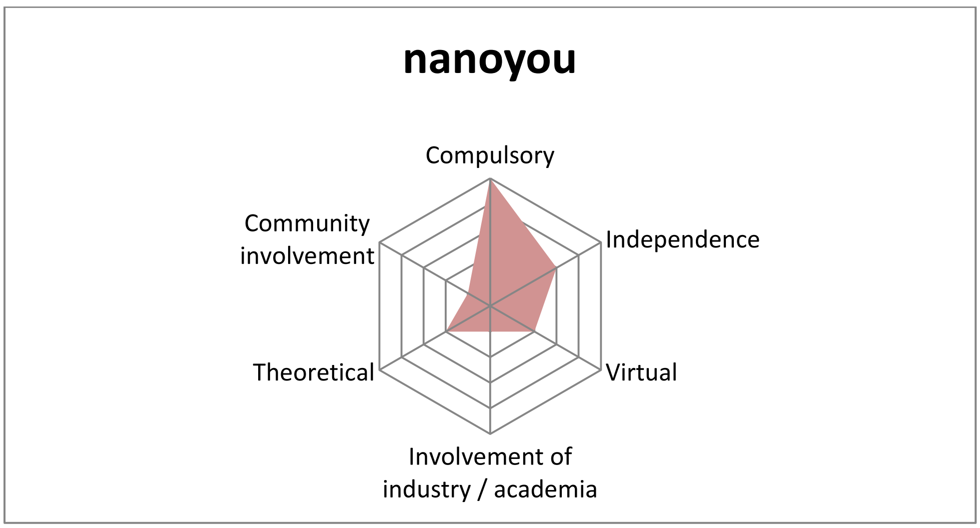
Short description: An EC-funded project (2009-2011) designed to implement a nanotechnology communication and outreach program aimed at European youth. The materials were developed for 11-18 year olds by means of school programs and a travelling exhibition. The materials and content of the project are available in 12 languages.

Target group: Students on various academic levels.

Materials developed: Teachers' guide (with background materials), role-play games, self-learning virtual activities, experiments, travelling exhibition, "The Strange New World of Nanoscience" film.

Program profile

Key person interview: Mr. Yoel Rotschild, NanoYou project coordinator



1. **Compulsory vs. voluntarily** – The outreach was primarily implemented with the teachers during school hours.
2. **Independent subject vs. integrated** – Some of the schools taught NST as an independent subject, while others integrated it in the science courses.

3. **Virtual vs. frontal teaching** – Most of the materials were taught using the frontal method.
4. **Involvement of industry/academia** – None.
5. **Theoretical vs. hands-on** – Only a minority of the content resources involved pure theoretical studies, it was mainly composed of role-paying, experiments, etc.
6. **Community involvement** – None.

1.2. NanOpinion

Website: http://nanopinion.eu/; Education portal: http://nanopinion-edu.eu/

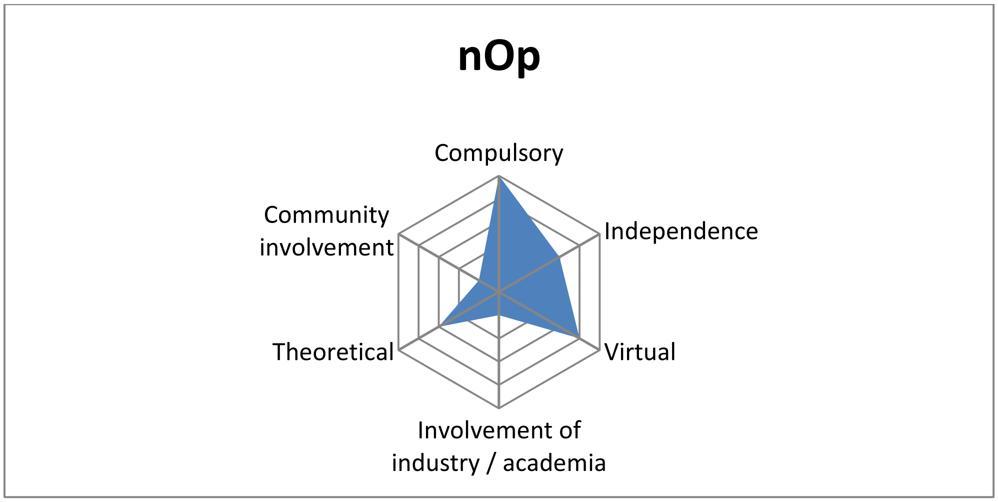
Short Description: An EC-funded project (2012-2014) aiming to monitor public opinion regarding innovation through the use of nanotechnologies. The project is aimed at citizens with a special focus on hard to reach target groups, i.e. populations which do not normally encounter nanotechnologies first hand nor express opinions on them. The eight modules in the education portal are aimed at secondary schools, and were translated into eight languages.

Target group: Students on various academic levels.

Materials developed: Moodle virtual learning system which includes eight modules, that divided into three themes. Each module contains an online self-learning section and a classroom ELSA discussion.

Program profile

Key person interview: Mag. Ilse Marschalek, NanOpinion project coordinator



1. **Compulsory vs. voluntarily** – Part of the learning is done during school hours.
2. **Independent subject vs. integrated** – The modules can be taught as an independent subject, but there are also recommendations on how to integrate the different modules into other subjects.
3. **Virtual vs. frontal teaching** – Mostly virtual; the discussions can be done in the classroom or online.
4. **Involvement of industry/academia** – None.
5. **Theoretical vs. hands-on** – Along with the theoretical material, a few experiments were also developed.
6. **Community involvement** – None.

2. National Governments

NST studies can be found in some European curricula as a topic within one of the science subjects. It is usually not a compulsory subject and it is often aimed at high-achieving students. The following examples are from three countries that had integrated NST in the school curricula.

2.1. Spain

Website: http://www.cienciasmc.es/web/u0/index_u0.html

Short description: NST is a mandatory subject for first year of *Bachillerato*, Spanish secondary school. The educational materials were commissioned by the Spanish Ministry of Education and developed by the Didactic Institute at the University of Valencia, Spain. The materials (developed by the University of Valencia), were edited by the ministry and each region is free to adapt the content to its needs and preferences (mainly with regard to regional language - Spanish, Catalan and Basque). The majority of students in tenth grade learn this curriculum (out of some 650,000 total students). One of the subjects is called "New Needs – New Materials", in which one of the articles reviewed is "New Technology: Nanotechnology".

The subject is versatile and offers various possibilities for integrating NST-related lessons. The subject aims to foster students' understanding of the importance of science in society and it aims to provide basic knowledge that can help them read information and news about science from a critical and objective perspective.

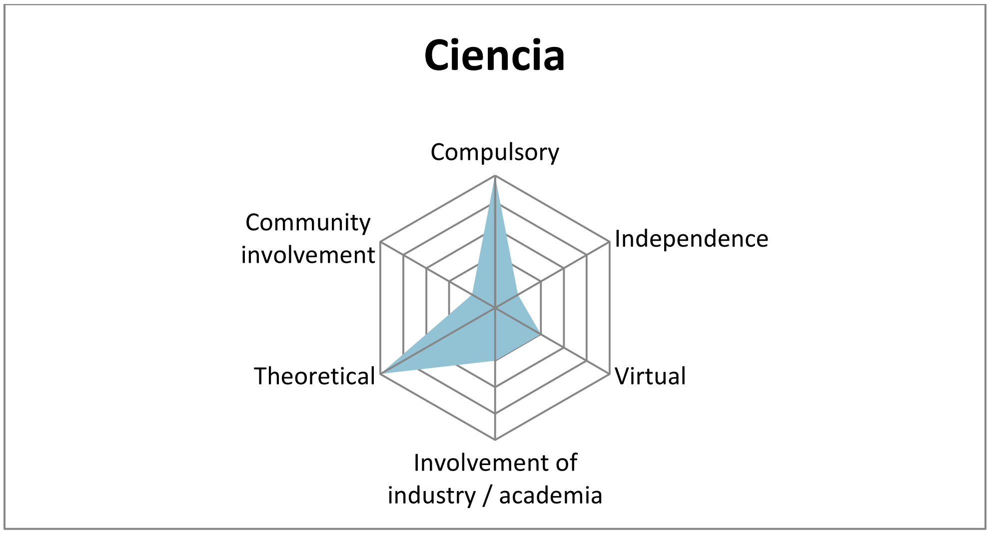
"Science for the Contemporary World" is taught 2 hours per week, within which NST is compulsory for 8 hours per year (excluding homework assignments). The purpose of the subject is to give the students an understanding of the cutting edge of scientific research.

Target group: Students on various academic levels.

Materials developed: Teachers' guide, student textbook (a chapter in a comprehensive science textbook), lesson plan, an introductory text, web quest activity and debate on risks vs. benefits of nanotechnology.

Program profile

The profile of this program was derived from official documents, materials and clarification from a Spanish education professional.



1. **Compulsory vs. voluntarily** – Compulsory by law. Each region is free to adapt the materials to its language and local needs.
2. **Independent subject vs. integrated** – The program is a chapter within a comprehensive science curriculum.
3. **Virtual vs. frontal teaching** – Primarily frontal teaching although schools are free to alter the methodology to their requirements.
4. **Involvement of industry/academia** – Written and revised academically; no further involvement.
5. **Theoretical vs. hands-on** – Mainly theoretical.
6. **Community involvement** – None.

2.2. Sparkling Science: Nanomaterials – Possibilities and Risks of a New Dimension (Austria)

Website: http://www.sparklingscience.at/en/

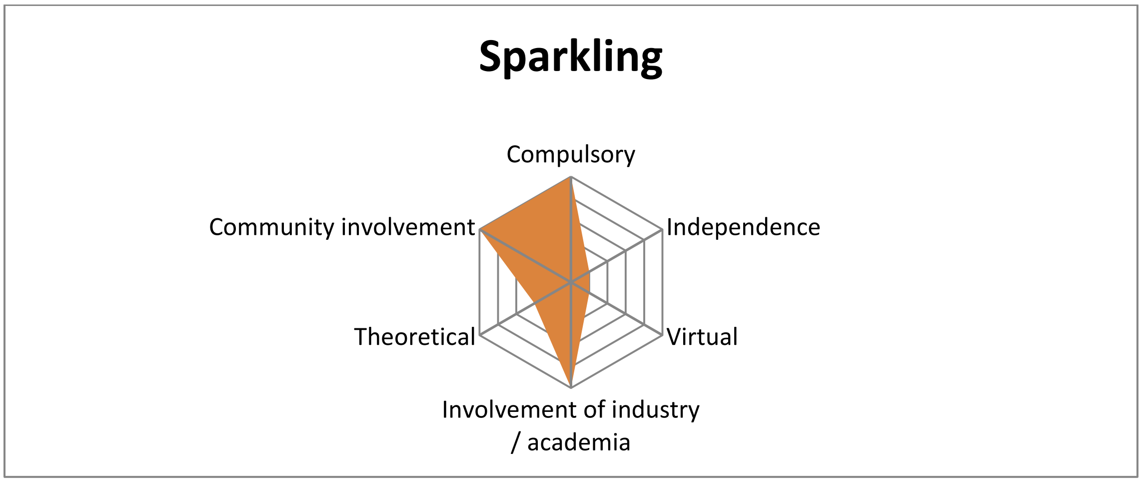
Short description: This program (2010-2012) belongs to the Sparkling Science project which was coordinated by the Austrian Ministry of Science and Research. It is a research program of the Federal Ministry of Science and Research (BMWF) which adopts an unconventional way of promoting young scientists that is unique in Europe. It has focused on practical experience with nanomaterials for students. The materials developed are available in German and aimed at 15 and 17 year old students.

Target group: High-achieving students.

Materials developed: Meetings with role-playing activities, discussion platform and quiz (teachers, students and scientists are involved in the project), young researcher workshop with posters on project highlights and problems.

Program profile

Key person interview: Dr. Marie Céline Loibl, leader of the Sparkling Science Funding initiative



1. **Compulsory vs. voluntarily** – Taught as part of school lessons within school hours.
2. **Independent subject vs. integrated** – Students learned the subject as part of science class (mainly physics).
3. **Virtual vs. frontal teaching** – There was almost no use of virtual resources for self-learning as part of this project.
4. **Involvement of industry/academia** – Each participating school was matched with a local university. Students and scientists presented their findings and discussed approaches of assessing the potential and risks of nanomaterials at the “Young Researchers Conference”.
5. **Theoretical vs. hands-on** – Most of the materials were theoretical.
6. **Community involvement** – As mentioned above, the students presented their project findings to the local community.

3. Regional Governments

In some EU countries the regional governments (länder, region, state, etc.) hold some degree of independence with regard to their education systems. The German land of Baden-Württemberg provides an example of introducing an NST program within a secondary school system.

3.1. Ministry of Education, Youth and Sport, Baden-Württemberg (Germany)

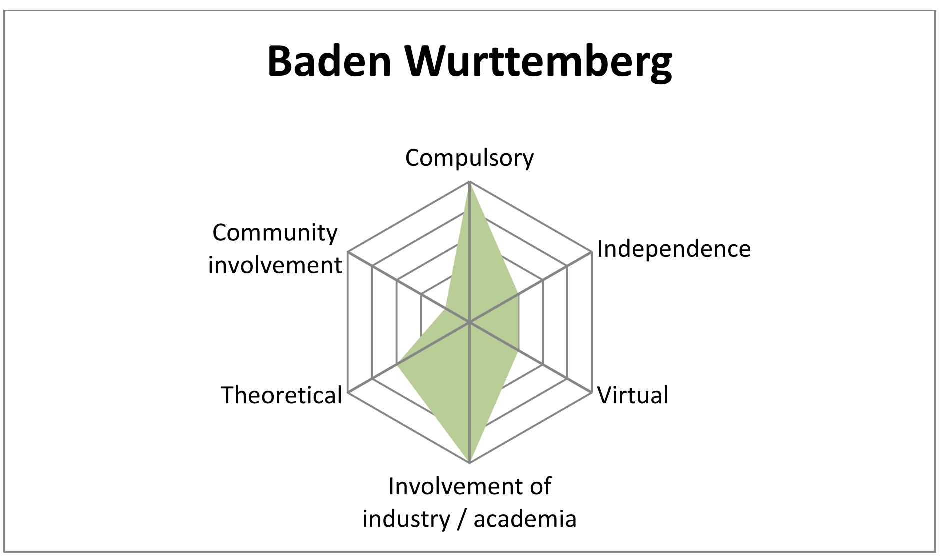
Short description: The regional ministry of the German land of Baden-Württemberg initiated a program for high-achieving students in secondary school (gymnasium) to promote the sciences. One of the topics that was chosen was NST. More than 70,000 students learned the one-year-long program.

Target group: Students on various academic levels.

Materials developed: Lesson plans, presentations, online activities, labs, excursions to research centres, excursions to industrial facilities, student projects.

Program profile

Key person interview: Dr. Gerhard Stern, science and techniques project specialist in the Ministerium Für Kultus, Jugend Und Sport Baden-Württemberg



1. **Compulsory vs. voluntarily** – The program was taught within the school schedule.

2. **Independent subject vs. integrated** – The subject of NST was taught as a topic within science and technology studies.
3. **Virtual vs. frontal teaching** – The materials developed included primarily frontal lessons with labs and excursions.
4. **Involvement of industry/academia** – As mentioned, there were some visits to research centres and excursions to industrial facilities. Moreover, lectures given by university professors were included as part of the teacher training.
5. **Theoretical vs. hands-on** – Integration of the two; there were frontal lessons along with labs, excursions to research centres, excursions to industrial facilities, student projects, etc.
6. **Community involvement** – None.

4. School Networks

The example of ORT Israel is unique, since it is the one of the few to have a year-long comprehensive program in NST for secondary schools. As of 2014 the program has been implemented in eight schools in the network.

4.1. Nanotechnology: What a Small World (Israel)

Website: http://nano.ort.org.il

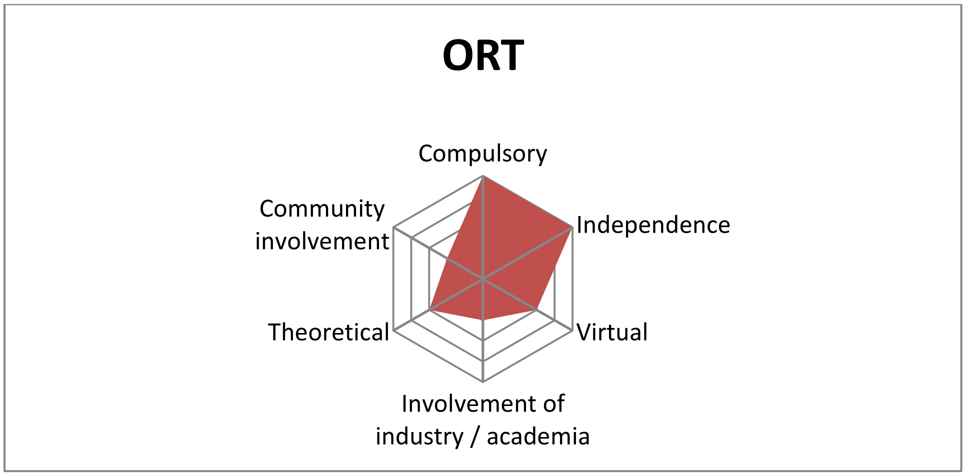
Short description: An ORT Israel school network innovation for teaching NST as a full, separate subject in science classes. The project (started in 2011) is a one-year (30 hour) program for junior high schools. Eight modules were developed (in Hebrew) for teaching the topic from its basic orientation to ELSA issues and future applications.

Target group: Students on various academic levels.

Materials developed: Web portal that covers the entire topic of NST including a teachers' guide, presentations, virtual activities, etc.

Program profile

Key person interview: Dr. Nira Shimoni-Eyal, project manager



1. **Compulsory vs. voluntarily** – The topic is taught as part of the school schedule and curriculum.
2. **Independent subject vs. integrated** – It is taught as an independent subject.
3. **Virtual vs. frontal teaching** – The program is designed as an integrated learning curriculum. Each module combines virtual and frontal learning.
4. **Involvement of industry/academia** – Limited; during the year there is one visit to an industrial facility where the students hear a lecture and have a tour.
5. **Theoretical vs. hands-on** – The theoretical learning is combined with experiments and role-playing.
6. **Community involvement** – Each school has one “Nano-day”, when parents and guests from the local community are invited to the school.

5. Academia

Apart from different types of collaborations with secondary school programs (as discussed above), there have naturally also been some programs initiated by NST centre staffs at various universities. These are usually initiated by senior staff members who introduce the subject to potential future students.

5.1. Nanolab (Italy)

Website: http://www.nanolab.unimore.it/en/

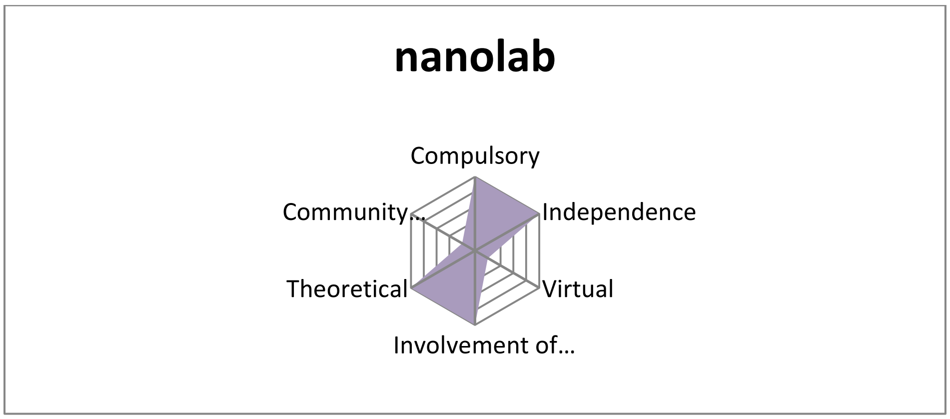
Short description: An educational project (started at 2008) of the Physics Department of the University of Modena and Reggio Emilia, Italy, for **science teachers** to integrate nanoscience into high school and undergraduate curricula. The department's Ph.D. students developed the materials and managed the project. The materials were developed and are available in Italian and English.

Target group: High-achieving students.

Materials developed: Lesson plans, student worksheets, presentations, experiments.

Program profile

Key person interview: Prof. Guido Goldoni, Nanolab project supervisor



1. **Compulsory vs. voluntarily** – Teacher participation was voluntary but the instruction was part of school hours.
2. **Independent subject vs. integrated** – The NST was taught as an independent subject.
3. **Virtual vs. frontal teaching** – Only frontal teaching.
4. **Involvement of industry/academia** – The materials were developed by the University of Modena and Reggio Emilia which also conducted the teachers' training.
5. **Theoretical vs. hands-on** – Mainly theoretical, along with labs and excursions.
6. **Community involvement** – None.

5.2. Nano in My Life (Ireland)

Website (for contact to receive a copy): http://www.crann.tcd.ie/Education-Outreach/School-s-Programme/Nano-in-My-Life.aspx

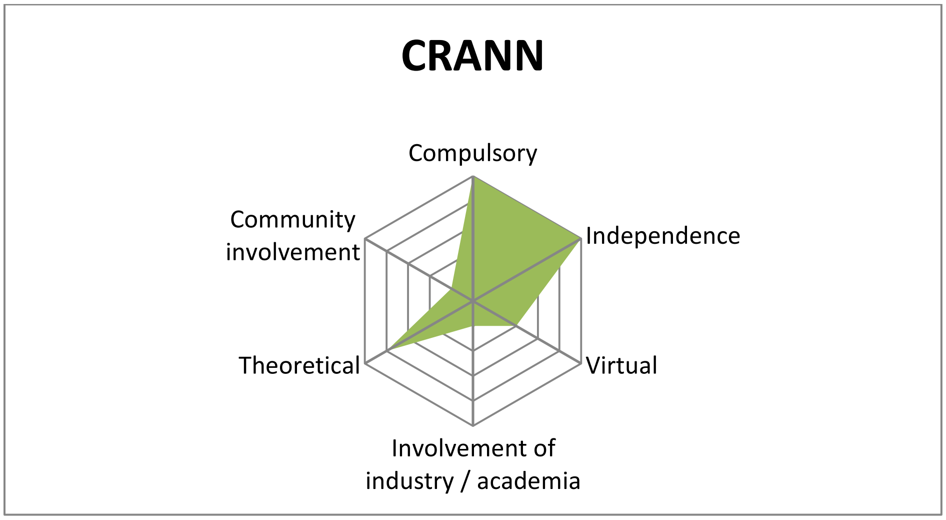
Short description: The Irish in-state CRANN (**C**entre for **R**esearch on **A**daptive **N**anostructures and **N**anodevices) developed the "Nano in My Life" educational program and launched it during Science Week 2011. There are seven modules, each of which uses a range of teaching and learning approaches designed to engage students and encourage active learning. The materials developed in English are aimed at high school students. The program was ordered by 196 schools, which is 26% of the secondary schools in Ireland.

Target group: Students on various academic levels.

Materials developed: Each module contains teachers' notes, a Power Point presentation, video, timings, experiments and worksheets.

Program profile

Key person interview: Dr. Mary Colclough, CRANN Institute Communications, Outreach & Public Affairs Manager



1. **Compulsory vs. voluntarily** – The materials were mainly implemented as part of the school schedule.

2. **Independent subject vs. integrated** – The whole program presents NST as an independent subject.
3. **Virtual vs. frontal teaching** – The program includes 2 CDs with lesson plans, videos and presentations designed for frontal teaching.
4. **Involvement of industry/academia** – None; it was only undertaken voluntarily.
5. **Theoretical vs. hands-on** – Mainly theoretical, though there are some experiments.
6. **Community involvement** – None.

5.3. Immersive Education: Interacting with Virtual Nanotechnology Environments in Building and Learning Fundamental Science Concepts (Sweden)

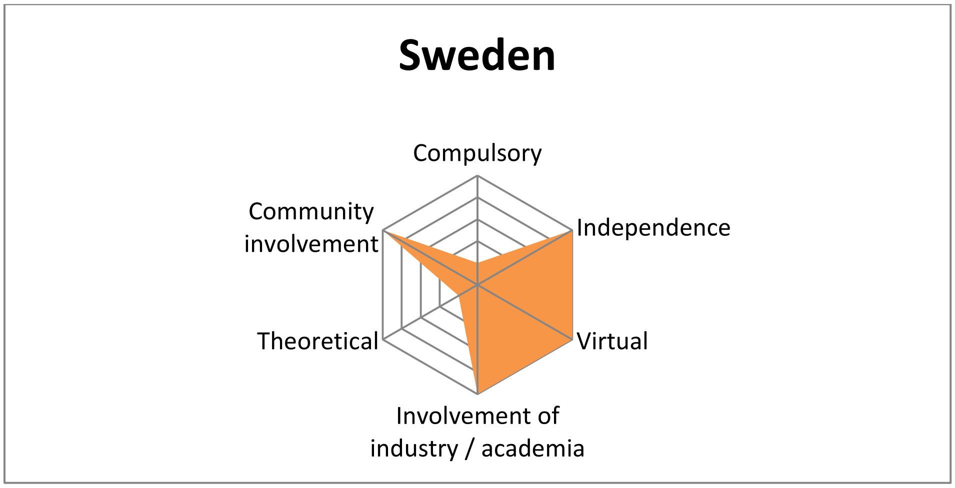
Short description: The project consists of three phases. Firstly, a virtual learning environment was developed that allows learners to construct an understanding of key scientific concepts based on interactions with nanotechnology scenarios. Secondly, the impact of students' interactions with the environment on meaning-making of fundamental nanoscopic ideas was investigated. Thirdly, pupils and the public's use of the environment in realistic classroom and science centre settings are currently being studied. Triangulation of mixed methods is employed to collect and analyse data including a suite of written, oral, interactive data. The project has direct educational, practical and theoretical implications for science didactics.

Target group: Students on various academic levels.

Materials developed: An exhibition, virtual reality tools.

Program profile

Key person interview: Dr. Konrad Schönborn, project instructor



1. **Compulsory vs. voluntarily** – The exhibition was open to the public yet the schools received a PC version of the exhibition to be used in classrooms.
2. **Independent subject vs. integrated –** Integrated.
3. **Virtual vs. frontal teaching –** Virtual.
4. **Involvement of industry/academia –** Initiated and produced by the university.
5. **Theoretical vs. hands-on –** Hands-on.
6. **Community involvement – The** exhibition was open to the public.

6. Industry

Industry has a crucial effect on secondary school students for two reasons. The first is the fact that some of the youngsters will be employed by industrial companies in the future (as seen in the example found below). The other reason is that the products manufactured by these companies can be found on store shelves, in hospitals, in vehicles, etc. Therefore, while some caution must be taken in order to avoid becoming too commercialized, industry should be involved in implementing NST into secondary schools.

6.1. Contipro (Czech Republic)

Website: http://www.contipro.com/contipro/csr-education/contipro-for-science

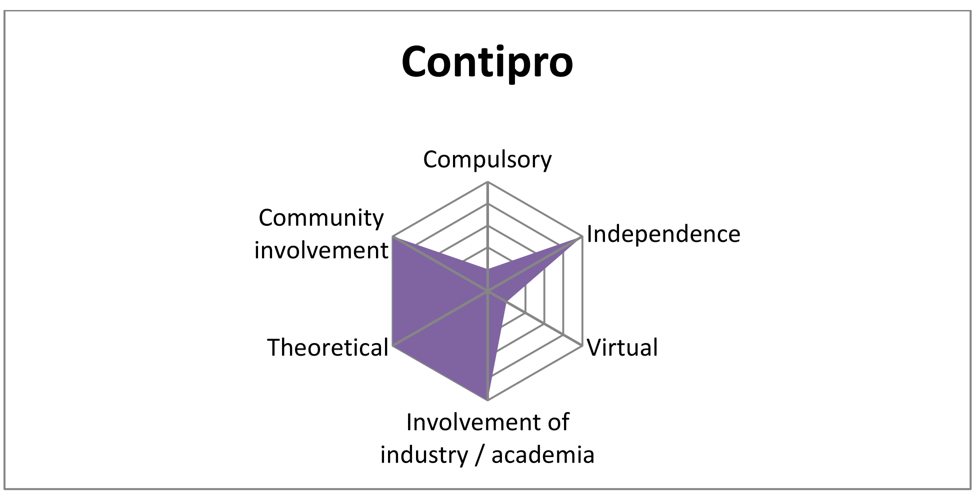
Short description: Contipro Biotech, Inc. is a company that manufactures hyaluronic acid and derived applications, located in a small town in the Czech Republic. In order to interest and train future local workers, they established a secondary school program in 2010. There are two components of the program: one is comprised of monthly lectures for school students and teachers about science and technology, given by professors from Czech universities (two to three of the lectures dealt with NST). As part of the other program component, 10 students are trained each year in an internship program in the company's R&D centre. The program continues to grow every year. On average, 21 students attended the lectures in 2010-11; in 2013-14 there were an average of 82 students in attendance at each one of the eight lectures. Moreover, some of the students who participated in the internship program went on to apply to work in the company.

Target group: Students on various academic levels.

Materials developed: Science and technology lectures.

Program profile

Key person interview: Mr. Tomas Papez, PR manager at Contipro



1. **Compulsory vs. voluntarily** – The participation is voluntary and outside of school hours.
2. **Independent subject vs. integrated** – NST was one of the topics covered in the lectures.

3. **Virtual vs. frontal teaching** – Only frontal teaching is involved.
4. **Involvement of industry/academia** – The program was initiated by the company, and the lecturers are from Czech universities.
5. **Theoretical vs. hands-on** – Since the main undertaking is the lectures and the internship is less central, the program is mainly theoretical.
6. **Community involvement** – The lectures are given to and for the local community.

7. Science Museums

Visiting a museum is a great learning opportunity for youngsters (and the public in general), whether the students are doing it as a school activity or on their own. The following program is a good example of how to make NST accessible for secondary school students through a science museum. Even though it was funded by the EC, it is unique in that the exhibition was integrated early on, but it is still operating even though the project has ended.

7.1. Deutsches Museum – Time for Nano (Germany)

Website: http://www.timefornano.eu/

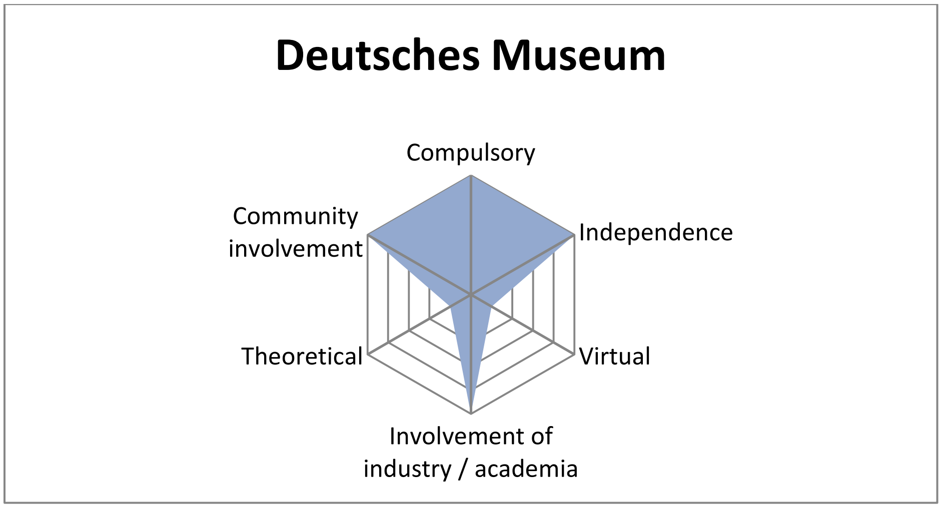
Short description: It is an EC-funded project which started in 2009. Among others, the main activity of this project was the development and design of an exhibition and operation of an open Nano laboratory (in Munich, Milan, and Gothenburg). The initiative has created innovative settings where a broad public audience can learn about and discuss nano research by directly interacting with the scientists themselves. The Deutsches Museum (Munich) placed the open lab in its Centre for New Technologies, which opened in 2005. The permanent “Time for Nano” open lab exhibition is one of the most popular activities among school groups. The museum conducts training for teachers to prepare them for the activities with their students.

Target group: Students on various academic levels.

Materials developed: Permanent exhibition of an open laboratory, experiments, hands-on activities, teachers’ training.

Program profile

Key person interview: Mr. Peter Schüssler, researcher at the museum's research institute



1. **Compulsory vs. voluntarily** – The visits that we refer to in this report are those which were undertaken as part of school activities, and which were therefore compulsory.
2. **Independent subject vs. integrated** – The exhibition activities only deal with nanotechnology.
3. **Virtual vs. frontal teaching** – All of the activities are face-to-face.
4. **Involvement of industry/academia** – The researchers that work in the lab are from local universities.
5. **Theoretical vs. hands-on** – Mainly hands-on activities.
6. **Community involvement** – The community is invited to visit this exhibition, like any other in the museum.

8. Local Initiatives

The last model that we examined is local initiatives – programs that will not take place without the teacher who initiated them, and who makes the effort to ensure that they will continue. Below you will find a good example of this kind of initiative.

8.1. Wertingen Gymnasium (Germany)

Short description: Mrs. Elisabeth Fehrenbach, a mathematics and science teacher at Wertingen Gymnasium (Bavaria) participated in 2007 in a teacher training program that introduced the subject of NST, and decided to bring it to her school. The students who chose to take the subject took a seminar course which consisted of two hours per week for one and a half years. The teacher also integrated the topic into the school's science classes.

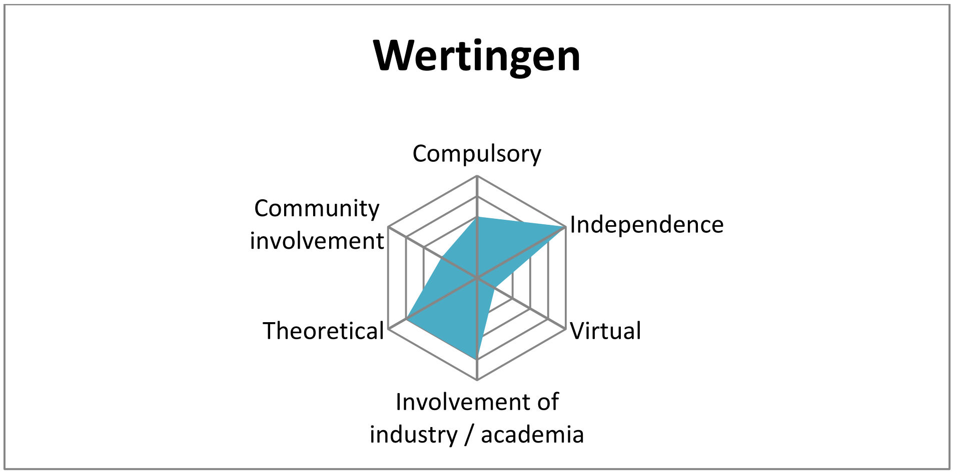
As part of the course, the students worked on presentations to demonstrate NST in different ways like building a model of a nanotube, or as a monopoly game. The students then had to present their projects to their peers.

Target group: Students on various academic levels.

Materials developed: Lesson plans, presentations.

Program profile

Key person interview: Mrs. Elisabeth Fehrenbach, Science and mathematics teacher at Wertingen Gymnasium

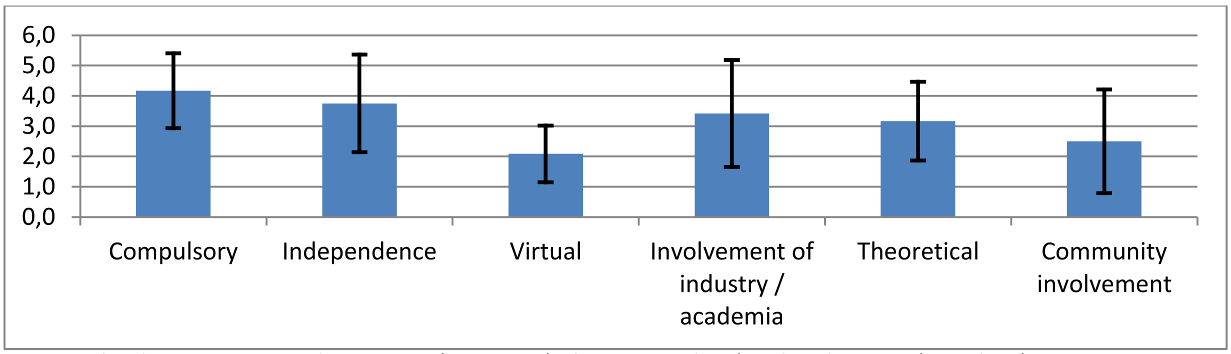


1. **Compulsory vs. voluntarily** – The program is integrated into the school schedule but the students can choose to take it or something else.
2. **Independent subject vs. integrated** – It is taught as an additional independent subject, independent of the regular science classes.
3. **Virtual vs. frontal teaching** – No virtual self-learning instruction involved.

4. **Involvement of industry/academia** – Augsburg University hosted students' NST presentations as well as a tour in their laboratories. The school also receives some sponsorship from industrial sources.
5. **Theoretical vs. hands-on** – The studies are mainly theoretical, but by the end of the seminar they have to work on a project (mentioned above) that includes hands-on activity.
6. **Community involvement** – None, though the projects are submitted to (and sometimes win) national competitions.

Conclusion

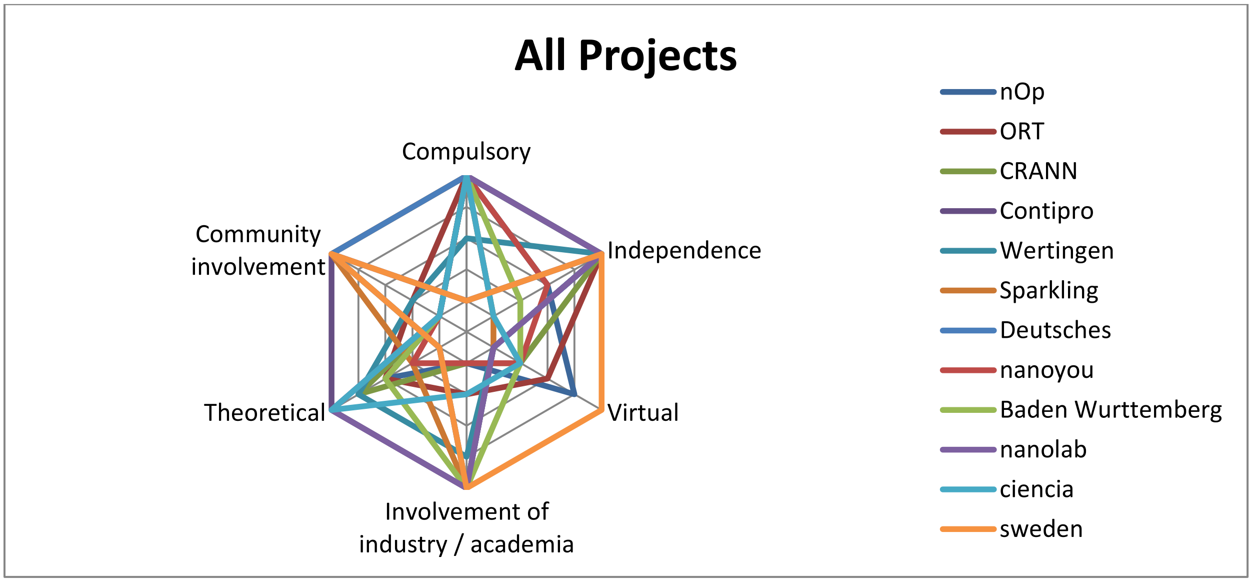
This report summarizes in-depth research performed into 12 projects in the EC and associated countries, presenting the best practice on different scales, from an EC-initiated project implemented throughout Europe down to a local initiative at a single school. The geographical heterogeneity was taken into account to ensure the report's validity. Each project was examined and scored according to six parameters in order to outline and compare the various profiles, strengths and weaknesses. This report will serve as foundation for formal recommendations on the matter.



The chart examines each parameter's average (column, scored 1-5) and its deviation (error bars)

The projects greatly vary in terms of the independence of the subject and cooperation with industry and academia. This variance suggests that mutual learning could greatly contribute to promoting good practices to more scalable nanoeducational approaches.

The following radar chart summarizes all of the project profiles:



What mainly stands out from this chart is the variety of projects in most parameters.

The projects shared similarity in three parameters: [1] most projects were compulsory; [2] all but three projects made use of a virtual platform; and [3] a high ratio of theoretical vs. hands-on pedagogical approach and practice. The projects greatly varied in the other three parameters: [1] the degree of independence i.e. is the project taught as part of an existing subject or as an independent subject; [2] the involvement of industry or academia; and [3] community involvement.

These results show that the main strength of a best practice project is being taught as a compulsory subject, albeit not necessarily one which is hands-on. These results has two meanings: [1] is that relying on voluntary attempts does not reach the audience of secondary school students and [2] that introducing hands-on activities to the classroom as a general practice has yet to be undertaken. Surprisingly, virtual platforms were not found to have been used very much and community involvement was generally scarce, as well. Virtual teaching methods could improve projects educationally, broaden the discourse and reinforce the reported benefits of community involvement while also addressing hard to reach audiences, as discussed in a previous EC-funded project, **NanoChannels** (2012).

The projects greatly vary in terms of the independence of the subject and cooperation with industry and academia. This variance suggests that mutual learning could greatly contribute to promoting good practices to more scalable nanoeducational approaches.

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- American Society for Quality (2006). **Radar Chart** http://rube.asq.org/education/docs/radarchart.pdf [accessed 21 September 2014].
- Blonder, R., & Dinur, M. (2011). Teaching nanotechnology using student-centred pedagogy for increasing students' continuing motivation. **Journal of Nano Education**, 3, 51–61.
- **Building a public consensus on NT** (2012). Carried out as part of NanoChannels project.
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- **Report on secondary schools education** (2013). Carried out as part of NanoEIS project.
- Roco, M. C. (2003). Converging science and technology at the nanoscale: opportunities for education and training. **Nature Biotechnology**, *21*, 1247–1249.
- **Selection of secondary school programs for in depth study** (2013). Carried out as part of NanoEIS project.

Key person Interviews

(arranged by their appearance in the report)

- Mr. Yoel Rotschild, 22 September 2014
- Mag. Ilse Marschalek, 23 September 2014
- Dr. Marie Céline Loibl, 23 September 2014
- Dr. Gerhard Stern, 23 June 2014
- Dr. Nira Shimoni-Eyal, 10 April 2014
- Prof. Guido Goldoni, 29 May 2014
- Dr. Mary Colclough, 25 July 2013
- Dr. Konrad Schönborn, 16 September 2014
- Mr. Tomas Papez, 12 May 2014
- Mr. Peter Schüssler, 14 May 2014
- Mrs. Elisabeth Fehrenbach, 13 May 2014

Appendix: NanoEIS Questionaire to Educators on Nanotech in Education

Dear Teacher/Educator,

The NanoEIS project (EU- FP7 project: http://www.nanoeis.eu/) is carrying out some research on secondary school Nanotechnology education. We would be grateful if you could dedicate a few minutes to complete the following questionnaire. Please note that information gathered through the survey will be used as part of an EU commissioned report on Nanotechnology Education for Industry and Society (NanoEIS).

General questions for educators

1. First Name
2. Country in which you are employed
3. Academic background in nano science?
4. Project name under which you teach NST
5. Subject matter – Physics, Chemistry, Biology, General science, other.
6. Grades (6-7th, 8-9th, 10-12th)
7. What is the ratio of girl's (approximately) in class (%) ?
8. How would you characterize your student's profile? (highly achivers, average achivers, low achivers)

Specific questions

1. Is the nano program which you are involved in a one-time event or more year/semester long event?
    1a. For year/semester long event: how many weekly hours are you involved in it?
    1b. For one time event: what are the total number of hours your are involved in the program
2. How many students participated?
3. What did/does the project entail? (frontal lessons, e-learning activities, labs, excursions to research centers, excursions to industry, experts visiting lectures, student's project, other)

4. What resources were/are used in the program?

4a. Teaching materials: (lesson plans, presentations, on-line activities)

Who supplied? (school, other)

4b. Labs?

Who supplied?

4c. Budget for excursions (to university and/or industry)?

Who supplied?

4d. Visiting experts lectures at school?

Who supplied?

5. How many hours of teachers' training were dedicated as preparation to the program?

6. Who organized the training? (school, local university, industry, teachers training center, other)

7. Do you have any on-going support (i.e. scientific advisory, pedagogical advisory, logistics and others)? (If so, by whom?)

8. Have you adapted any materials from previous projects in which you have participated?