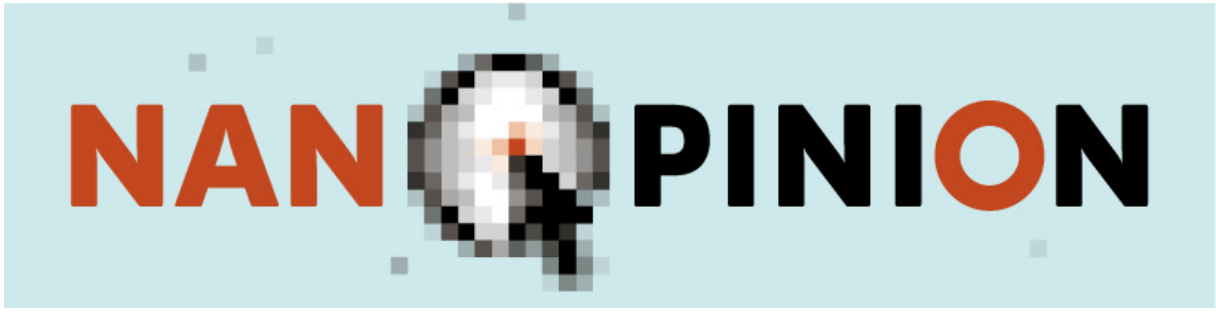

Monitoring public opinion on NST in Europe

European Platform on Nano Outreach and Dialogue (NODE)

(Grant Agreement NMP.2011.3-4-290575)

D*4.1 – School Mapping Report*

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School Mapping Report

1. Introduction

This report explores and suggests how to best incorporate Nanoscience and technology (NST) into 13 European school curricula (national and regional) involved in the NANOPINION project.

The NANOPINION project will use a number of applications to illustrate NST properties and technological perspectives. This mapping will thus analyse how each of these applications can be linked to the various parts of the specific curricula of the 13 curricula involved in the project.

The mapping exercise has the final aim to group together the EU Member States and associated countries involved in NANOPINION in terms of how nanotechnologies can be incorporated into their local curricula. We suggest some clusters of European countries to tailor how to use the NANOPINION platform for each cluster according to the flexibility of the school programmes and the level and space NST can take in the curricula.

2. Methodology

The report is elaborated on the basis of information given by science teachers from each of the 13 countries and regions acting as national/regional coordinator and on desk research carried out by EUN on the school systems.

All sources coming from scientific articles, public authority and organisations websites of this report are referred in footnotes. Whenever the source is not referenced, we imply that the information is coming from the Teachers Coordinators selected on a number of excellence criteria for the NANOPINION project.

The information gathered from the Teachers Coordinators was collected through a survey first tested by the Romanian teacher, then adapted and finally filed in by the rest of the team of Teachers Coordinators. The questionnaire can be seen in **Annex 1 NANOPINION survey - Mapping Nanotechnology in European curricula.**

The country reviews are based on suggestions and information given by science teachers from each of the 13 countries reviewed in this report. The name, teaching place and subjects of the teachers contributing to this report are listed below.

Country	Name	Subjects	Region	School
Bulgaria	Svezhina Dimitrova	Physics , Chemistry	Varna	Astronomical observatory and Private trade high school
Croatia	Ana Bedalov	Physics , Science	Split	Prorodoslovna tehnicka gimnazija
Czech Republic	Krajcova Vera	Physics , Maths	Prague	Smichovska stredni prumyslova skola
Denmark	Lotte Vett	Physics , Chemistry, Biology and Maths	Fyn	Nymarkskolen
Finland	Jukka Rahkonen	Physics , Chemistry, Maths	Muurame	Nisulanmäen koulu
Germany	Jörg Haas	Physics , Maths	Augsburg	Jakob-Fugger-Gymnasium
Greece	Stylianos Friligkos	Physics , Science	Thessaloniki	1st upper-Secondary model school of Thessaloniki
Israel	Sharon Alon	Biology , Science	Givataym	ORT GIVATAYM
Italy	Annamaria Lisotti	Physics , Maths	Pavullo (MO)	ISIS Cavazzi/Lic. sc. Sorbelli
Lithuania	Rima Baltrusaitiene	Physics , Science	Kaunas	Kaunas Kazys Grinius Progymnasium
Romania	Lidia Minza	Chemistry, Science	Galati	Vasile Alecsandri
Catalonia, Spain	Margarita Soriano	Biology , Science	Barcelona	INS Sant Just Desvern
Asturias, Spain	Rafael Montero	Physics , Science , Maths	Gijón	Corazón de María
Turkey	Gozde Mediha Kamer	Chemistry, Science	Istanbul	Uskudar American Academy

Figure 1: Team of NANOPINION Teachers Coordinators

The information collected from the Teachers Coordinators and from the desk research is structured first in country profiles. The second part is dedicated to cross-country comparison and grouping to propose clusters based on the curriculum flexibility and the strategies to integrate NST in the schools programmes.

The mapping report was also made in collaboration with the work package of the project taking care of monitoring the outreach and public attitude towards NST (WP6). The methodology, the choice of countries to involve in the formal education activities and the research linked to this report were discussed with ORT Israel, ZSI, STSSCZ, LYITCC, AU, BC and BFR.

The present report serves as preliminary research to best incorporate NanOpinion activities in the schools taking part to the project. The activities in formal education settings will be assessed thought the monitoring made in WP6 of the project.

The final version of this report also results from a review by the partners involved in the task **T4.1 Using the NANOPINION platform in schools – schools mapping**.

3. Countries and region review

The selection of countries taking part in the NANOPINION activities related to outreach and dialogue in Formal Training and education settings has been guided first by the location of the project partners. In addition to the main support provided by European Schoolnet, the Teacher Coordinators and schools benefit from the expertise and knowledge of the national and local context of the partner. Some partners' organisations that have their activities related to formal education are involved in the organisation of the national workshops to engage teachers in the NANOPINION activities (ORT Israel, iNANO Denmark, Parc Cientific de Barcelona and STSSCZ in the Czech Republic). Other partners' organisation will support the activities at national level mainly in terms of dissemination or methodology (El Mundo in Spain, BfR in Germany and Il Sole 24 Ore in Italy). Five additional countries have been included in the programme, following the applications from teachers to support education outreach activities of NANOPINION.

3.1 Bulgaria

Education in Bulgaria is overseen by the Ministry of Education and Science. The different science subjects have their own educational programs regulated nationally.

Full-time education is mandatory for all children aged between 7 and 16. Student of 13 to 16 years old are generally at the secondary school level.

Compulsory Education	Age
Natchalno utchilishte (primary school) 1st to 4th grade	6-10
Progimnazialno utchilishte (basic school) years 4th to 8th grade	11-14/15
Secondary education options: • **Gimnazia (Upper secondary school)** • **Profilirana gimnazia (Upper schools of specialized studies profile)** • **Profesionalni uchilishta (Vocational schools)** • **Professionalni gimnazii (Vocational secondary schools)**	14/15-19

Table 1: Compulsory Education Bulgaria

There are two kinds of secondary schools "General secondary education schools" and "Professional schools". For the award of a diploma for secondary education student

must take two matriculation exams, one in Bulgarian language and literature and a second subject chosen by the student. After the successful completion of matriculation exams, students are awarded a diploma for secondary education and can apply for higher education. [1]

Although the curriculum of each subject is regulated at a national level each teacher has flexibility to shape the curriculum on an individual basis. The individual curriculums are approved by the school director to ensure it live up to the national curriculum requirements.

In Bulgaria NST is not a mandatory subject, chapter or topic in any of the science curriculums at the secondary school level, but it could be integrated as sub-topics in Biology, Physics and Chemistry. The attainment target level for students would be to introduce an essential understanding of NST on the basis of theoretical knowledge supported by practical examples of NST products.

It would be feasible to integrate NST teaching in the curriculum because each teacher has a certain level of autonomy when applying the curriculum. It is relatively easy for each teacher to devote hours to teach NST during a school year. There are no plans to integrate NST in the curriculum on a general national level known at the moment.

The applications of NST used in NANOPINION project can be linked with the Bulgarian curriculum as follow:

- **Medicine and drugs using Nanotechnology** are not applications that are covered by the curriculum but they could find a place in Biology and Chemistry in Grade 9 (15 years old students), stage at which students learn organic Chemistry and Chemistry of the cell, and in the Chemistry course of Grade 10 (16 years old students) when chemical kinetics and technology are taught.

- **Environment and energy using Nanotechnology** are covered as subtopics in Physics and Chemistry. These applications of NST could find a place in the curriculum of Physics at 7th, 9th and 10th Grades, when students study energy and in Chemistry at 7th and 10th grade.

- **Electronics and sensors made with Nanotechnology** are also covered as subtopics. Physics is integrated in the curriculum of Physics at 7th and 9th grade, when electrostatics, electromagnetism and the electric current are approached.

- **Consumers products based on nanotechnologies** are not part of the curriculum so far but they can be linked to Physics, Chemistry and Biology from the 5th to the 12th grade.

3.2 Croatia

In the education system of Croatia, primary education is compulsory and lasts eight years (6-14 years). Secondary school education (14-18), which is not compulsory,

[1] EURYPEDIA (2011a),

lasts three or four years, depending on the type of education. General education is provided in Gymnasiums specifically meant for pupils who plan to continue their education towards higher education. All public schools, both elementary and secondary schools are free of charge for everyone and most of them are public. The Ministry of science, education and sports regulates the school programme. [2]

Compulsory Education	**Age**
ISCED 1 & 2 Osnovna škola (Compulsory primary & lower secondary education)	6/7-14/15
lower secondary general education • **ISCED 3A - Gimnazija (Gymnasium)** • **ISCED 3A - Tehničke i srodne strukovne (Technical and related vocational)** • **ISCED 3C - Obrtnički i industrijski (Vocational)**	 14/15-18/19 14/15-18/19 14/15-17/18

Table 2: Compulsory Education Croatia

In Croatia NST is not a chapter in itself in one of the scientific subjects but addressed as a topic in the scientific curriculum. NST is integrated in national curriculum only during the fourth and last year of secondary school (students age 17-18).

NST is integrated in the Physics curriculum under the chapter "Materials and materials properties" under the sub-chapter "Atoms, nucleus and elementary particles". The learning goals for students are to explain some of the effects of semiconductor electronics and Nanotechnology. This chapter represent about 2 hours per school year.

NST is also integrated in the Biology syllabus under the chapter "Nature and Men", under the specific subchapter named "sustainable development". Here the learning goals for students are to explain why there is a need to develop new technologies (fusion, new fuels and Nanotechnology). Biology represents about 2 hours per year.

There are no indicators of new initiatives to integrate more knowledge on NST in the national curriculum in a near future, but schools generally seem open to any extracurricular activities in science and NST. A strategy to integrate more NST in the Croatian curriculum could be through a bottom-up approach designing short exercises related to different topics of the curriculum. Each demonstration or exercise should not take more than 10 to 25 min. This way NST could be integrated in classes without asking permission from state authority and without instant need to change national curriculum.

NST could additionally be integrated in the school curriculum in subjects and topics where ethics or debate clubs are central. Often students find the need to discuss the

[2] Tsuladze, Lia (May 2012)

benefit of Nanotechnology for society and its risks. For example the Nanochannels project[3] gave space to positive discussions in Croatia among students, teachers and even scientists on the benefits of Nanotechnology.

As per the specific applications of NST that will be used in the NANOPINION project, according to the Croatian Teacher Coordinator, medicine and drugs using NST and Consumers products based on Nanotechnologies are not covered by the curriculum. On the other side, environment and energy as well as electronics and sensors made with NST are covered as a subtopic in one of the science courses.

3.3 Czech Republic

Education in the Czech Republic is free and compulsory for the elementary education which takes nine years, from ages 6 to 15. Children can obtain their elementary education at a variety of different schools that can also utilize different types of educational programs. Most commonly, children attend a regular 9 year elementary school.

Compulsory Education	**Age**
Primary and lower secondary education is organised mostly within a single-structure system by základní školy (basic schools). **Lower secondary education can be provided also by:** • **víceletá gymnasia (multi-year gymnázia) and;** • **osmileté konzervatoře (eight-year conservatoires).**	6 to 15
NB: Non compulsory **Upper secondary education is provided by:** • **střední školy (upper secondary schools)** • **vocational fields** • **konzervatoře (conservatoires)**	15-19

Table 3: Compulsory Education Czech Republic

The Czech Ministry of Education, Youth and Sports is responsible for the educational policy. This institution formulates the long-term policy objectives of the development of the education system every four years. The responsibility is distributed between the

[3] http://www.nanochannels.eu/

central government, the 14 regions and the communities. The communities are responsible for compulsory schooling. They establish and administer basic schools. Schools have the status of legal entities.

School heads were given full responsibility for the quality of the educational process, the financial management of the school, appointing and dismissing teachers and relations with the community and the public. By law, the school organising body must establish a School Council so that parents, pupils, staff, and the public can participate in the administration of the school. This means that the educational system has a certain level of local autonomy toward the general national objectives. [4]

NST is not a mandatory subject, chapter or topic in the national curriculum but it is possible to integrate it to Physics, under the topic "atomic Physics" representing 10 hours in the curriculum of the fourth year of study in Chemistry and Biology subjects.

As per the specific applications of NST that will be used in the NANOPINION project, according to the Czech Teacher Coordinator, medicine and drugs using Nanotechnology could be linked to Biology of human. Environment and energy as well as electronics and sensors made with Nanotechnology and consumers products based on Nanotechnology (Sport, clothes…) could be approached during some hours of Physics (2 hours per week in all years of study; Technical lyceum - 3 hours per week in all years of study) or in the subject called electrical engineering (2 hours per week in the first year of study).

[4] Eurydice study (2008/09),

3.4 Denmark

The Danish curriculum has a national scope. It is formulated by the Danish Ministry of education. The Danish school system comprises the Folkeskole, private elementary schools and continuation schools. The Folkeskole (Primary and Lower Secondary Education) is a comprehensive school system including the first (grade 1 to 6) and second (grade 7 to 9 or 10) stage of basic education for students aged 7 to 16 or 17-year-olds. The Folkeskole includes one year of pre-school class, nine years of primary and lower secondary education and the 10th form. Education is compulsory in Denmark for every child between 7 and 16 years old. This education can be given in a public school, in a private school or at home, as long as accepted standards are met. [5]

Compulsory Education	Age
Folkeskole (primary and secondary education)	6-15/16
lower secondary education orientations: • **Gymnasium** • **Handelsskole/Tekniskskole** • **Erhvervsskole**	 15/16-18/19 (15/16-21)

Table 4: Compulsory Education Denmark

The continuation schools consist in three-year upper secondary education programmes accessible to students that have completed the nine years of Danish basic education and have succeeded the final examination of the primary and lower secondary school. There are four different upper secondary education programmes: STX, HHX and HTX. The objective of the continuation schools programmes is to prepare students for tertiary education. The STX and HF programmes proposes subjects related to the humanities, natural science and social science. The HHX programme concentrates on business and socio-economic disciplines with foreign languages and other general subjects. Finally, the HTX programme focuses on technological and scientific subjects. The Ministry of Education determinates curricula for subjects and multi-subject courses of the upper secondary schools. [6]

Every subject in the primary as well as the secondary school is described by the subjects' objective description, the attainment targets and the endpoints. For example the subject Physics/Chemistry includes the following four areas:

1. 'The world of Physics/Chemistry';
2. Development within scientific recognition;

[5] Website of the Danish Ministry of Education.
[6] Website of the Danish Ministry of Education.

3. the use of Physics and Chemistry in society
4. everyday life and working method and ways of thinking

In Denmark, Nanotechnology is not a mandatory subject, chapter or topic in the curriculum. However it could be integrated as Nanoscience which includes elements of Chemistry and Biology.

The attainment targets for students to be set when teaching NST could be related to existing ones (in the current Danish science curriculum) such as the ability to formulate simple problems, compile and verify hypotheses and assess results but also to disseminate results of work on physical, chemical or technical issues. The students would also acquire knowledge on research activities that have provided new knowledge and unforeseen opportunities.

New attainment targets would be the knowledge of technical applications of science in everyday life, including Nanotechnology. Students would also learn how the need for technology has facilitated the development of practical and theoretical knowledge, including Nanotechnology.

The types of activities that could be proposed when teaching NST could be for instance related to the importance of the surface in relation to the rate of reaction. This could be done with hands-on activities using sugar dissolved in water. The teacher could for example explain the surface tension of the water using practical example such as the difference between caster sugar versus sugar cubes explaining. Another activity would be to investigate the application of Nanotechnology in sun protection creams.

The Danish Teacher Coordinator suggest to dedicate 3 hours a week during 4 weeks in the 9Th Grade. She further suggest to find ways to cooperate with science-high school teachers and see their curriculum.

All though the subject is not a part of the Danish curriculum, it is very important that the subjects taught reflects what is going on in the surrounding community.

Several programme led by universities to collaborate with the Folkeskolen to integrate NST in the teaching exist in Denmark. The University of Copenhagen and the University of Aarhus have developed teaching materials for the schools that teachers can integrate on a voluntary basis.[7] Both universities allow visits in their Nanoscience Centre proposing experiments to students.

The interdisciplinary nanoscience Centre of Aarhus University proposes a booklet with an introduction to nano range and 12 examples of current research of the Center, iNANO at Aarhus and Aalborg University. The articles are written by the researchers working on topics in the laboratories on a daily basis, and explains how nanotechnology is being studied in laboratories today and tomorrow.[8] Aarhus University also proposes a

[7] Website of the Nanoscience Centre of the Copenhagen University - http://nano.ku.dk/folkeskolen/
[8] Website of the interdisciplinary Nanoscience Centre of the Arhus University http://inano.au.dk/outreach/besoegsservice/undervisningsmateriale-i-nanoteknologi-til-gymnasiet/

magazine and a teacher guide with information given by Danish scientist in nano-science to teachers.[9]

3.5 Finland

Finland has a nine-year long compulsory school system for children aged 7-15. The education system is publicly funded. As described by the Ministry of Education: "*The Ministry of Education and Culture and the National Board of Education are responsible for implementing education policy and for administering the education system at the central government level. However, many matters are decided by the education and training providers themselves, that is, local authorities and their consortia. Pre-primary and basic education and upper secondary general and vocational education are governed by objectives set in legislation and by national core curricula. General education and vocational training are co-financed by the government and the local authorities.*"[10]

The municipalities have the autonomy to adjust the curriculum to local preference and needs of their schools. Next new national curriculum will be given to municipalities in 2014. This review focuses on the national curriculum of the last year of the compulsory schools of Finland. It is important to note that in the Finnish educational system teachers have relatively deep involvement in curriculum development processes[11].

Compulsory Education	**Age**
Perusopetus/Grundläggande utbildning (basic education)	Age 7-16

Table 5: Compulsory Education Finland

In Finland, NST is not a mandatory subject, chapter or topic in the national curriculum but due to the local adjustments it is possible to integrate NST in various ways.

A research on the problematic to integrate NST in the Finish curriculum was conducted by Antti Laherto in 2011. The research had the objective to initiate a process in Finland by learning from the views of Nanoscience and Nanotechnology-informed science teachers on the needs and prospects of NST education in secondary schools. From a methodological point of view, the study is based on one of the components of the Model of Educational Reconstruction[12] of NST, namely, the analysis of educational significance. This model is useful as it establishes a frame for improving instructional planning and science education research.

The respondents' opinions of Antti Laherto study reveals that when it comes to organising instruction on NST in practice, teachers expressed very sceptical views: "*The teachers were unanimous in their estimation: currently their schools have only poor*

[9] Website of the online magazine 'hvad er nano?' (What is nano?) http://www.hvadernano.dk/
[10] Website of the Finish Ministry of Education.
[11] Laherto, A. (2011)
[12] Duit, R., Komorek, M., & Wilbers, J. (1997).

resources or no resources at all to provide education on the topics in question. The respondents pointed out several problems related to physical and mental resources. Still, all of the teachers emphasised that in-service teacher training would be the key issue to improve the capabilities". [13]

The study also brought out that incorporating NST into existing science courses appears difficult since these topics are not explicitly in the Finnish curricula (FNBE, 2003, 2004), and there is hardly any space for additional contents. On the other hand, arranging extra courses (optional for upper secondary school students) requires money for teacher person-hours. Many respondents of the study of Antti Laherto expressed that addressing NST in science lessons depends completely on themselves and other individual teachers.[14]

Despite these structural problems raised by Finnish teachers, respondents to Antii Laherto study, according to the NANOPINION teacher coordinator, NST could be included in several places of the curriculum. NST could be approached in the Physics curriculum in the chapter called "The structures and the dimensions of the nature". In the Chemistry curriculum it could be included in the chapter called "Explaining the structures and quality of the elements and compounds".

In particular NST could be taught during the last compulsory school year (9th grade students) giving the students a basic introduction to the subject and understanding of its current and future research possibilities. According to the Finish NANOPINION Teacher Coordinator, five teaching hours of NST can be integrated within the 9th grade school year: one lesson for the basic theory, two lessons about applications today and in the future, and two hours for practises and experiments, to give students the opportunity to have some hands-on activities.

At the moment Finland is drafting a new Physics curriculum. The new curriculum will be ready in 2014, but it is too early to present the outcome and the integration of NST topic.

As per the application of NST, medicine and drugs could be connected to the Chemistry subject under the chapter "Organic nature and the society". There is already one subtopic under that chapter about detergents, cosmetics and textiles. Adding medicines could be done easily. The application of NST in environment and energy domains could be taught in the Physics curriculum in mechanics chapters (mechanic energy) and heat (conservation of energy, heat and energy) and electricity. Electronics and sensors made with NST could be easily connected to the chapter called "Electricity". Approaching the applications of NST in consumer products could be done in the subtopic from the Chemistry curriculum including textiles, where nano-clothes could be taken as illustration. Finally, sports products based on NST could be introduced in the Physics curriculum in the mechanics chapter.

[13] Laherto, A. (2011), idem
[14] *Ibidem*

3.6 Germany

Germany comprises sixteen states which are collectively referred to as Länder. The German curriculum is formulated by these sub-national levels (states). The German NANOPINION Teacher Coordinator is from the state of Bavaria, state in charge of the curriculum in his school. We will focus on the state of Bavaria for the mapping of curriculum exercise in Germany.

Compulsory Education	Grade	Age
Grundschule (primary education)	1 - 4	6-10 (6-12, Berlin & Brandenburg)
Orientierungsstufe (lower secondary education)orientations: • **Gymnasium/Realschule/Hauptschule/Gesamtschule** • **Schularten mit mehreren Bildungsgängen (types of schools offering several courses of education)**	5 - 9	 10-12 10/12-15/16
Gymnasiale Oberstufe (general upper secondary school) orientations has the following school types: • **Gymnasium/Berufliches Gymnasium/Fachgymnasium/Gesamtschule** • **Berufsfachschule (full-time vocational education)** • **Fachoberschule (full time vocational education)** • **Berufschule and Betrieb (part-time vocational school and part-time on-the-job training)**	10 – 12 or 13	15/16-18/19

Table 6: Compulsory Education Germany

Nanotechnology is not a mandatory subject, chapter or topic in the curriculum of Bavaria. As in other countries, the subjects NST can be related to Biology, Physics and Chemistry. In form 6 and 7 (12-14 years old students) the curriculum comprises a subject called Nature and Science where basic knowledge related to NST can be taught.

In addition, students can choose to have more STEM[15] lessons from form 8 to form 12 (ages 14-18). In these additional lessons the curriculum only offers proposals to the teachers. Teachers are quite free to choose subjects. From the Teacher Coordinator point of view this is a perfect way to test and prepare a NST curriculum for the next update. In this special science option, there is an additional lesson in Physics and one in Chemistry each week.

[15] STEM: science, technology, engineering, and mathematics.

According to the German Teacher Coordinator, teaching NST all year long is not possible due to the current structure of the curriculum but half a year would be feasible. The German Teacher Coordinator highlight the fact that the best and highest motivating way to teach science is to let the students learn by doing experiments. It must imperatively be taken into account to teach NST.

In addition to the hours used to teach NST in STEM classes, some lessons from English and German can be used to introduce the ELSA[16] aspects.

On the perspective to add NST in the curriculum, there are some initiatives especially in Bavaria that established for example a schools award for Nanotechnology (http://www.initiative-junge-forscher.de/jugendliche/schulwettbewerb.html). In addition, a plan exists to publish a school book about Nanotechnology for the next term.

The curriculum currently taught in Bavaria is about 5 years old and the hope is that Nanotechnology will be a part of the new one.

As per the specific applications of NST that will be used in the NANOPINION project, according to the German Teacher Coordinator:

- **Medicine and drugs using Nanotechnology** are topics that could be integrated in Chemistry and Biology
- **Environment and energy applications using Nanotechnology** could be easily link to the curriculum as environment topic is fixed in nearly all subjects in the secondary school. The energy topic is present in the curriculum of form 8 and 10 (14 and 16 years old students) and renewable energies are quite important there (e.g. pv-cells with nano-coatings)
- **Electronics and sensors made with Nanotechnology** could be approached during Computer Science course in form 9 or 10 (15-16 years old students) when the reduction of the size of processors is tackled.
- **Consumers' products based on Nanotechnology** (Sport, clothes…) can be tackled in form 6 and/or 7 (12-13 years old students). It could be done for example using the lotus-effect as illustration, an easy experiment to teach and carry on.

3.7 Greece

Education in Greece is compulsory for all children 6-15 years old; namely, it includes Primary (Dimotiko) and Lower Secondary (Gymnasio) Education.

The Greek educational system is mainly divided into three levels, mainly primary, secondary and tertiary, with an additional post-secondary level providing vocational training. Primary education is divided into kindergarten lasting one or two years, and primary school spanning six years (ages 6 to 14).

[16] ELSA: Ethical Legal and Social Aspects

Compulsory Education	Age
Nipiagogeio (pre-primary education)	5-6
Dimotiko scholeio (primary education)	6-12
Gymnasio (lower secondary general education)	12-15

Table 7: Compulsory Education Greece

As described by the Greek Ministry of Education: "*Post-compulsory Secondary Education, according to the reform of 1997, consists of two school types: Eniaia Lykeia (Unified Upper Secondary Schools, translated as Middle or Junior High School) and the Technical Vocational Educational Schools (TEE). The duration of studies in Eniaia Lykeia (EL) is three years and two years (a' level) or three years (b' level) in the Technical Vocational Educational Schools (TEE). Mutual student transfer from one type of school to the other is possible.*" [17]

In addition to Lykeion and vocational training, the secondary education system (ages 14 to 19) also include a third type of schools, the special schools. Special schools belong to one of the following types:

- 3a. Schools for students with special education needs,
- 3b. Schools of music studies,
- 3c. Intercultural education schools and
- 3d. Model schools (schools with the mission of designing, implementing and testing educational innovations).

Curriculum for all secondary education schools, is formulated at national level by the Ministry of Education, according to the guidelines provided by the Institute of Educational Policy. Moreover all schools use the same set of course books and supplementary material. Only model schools (type 3d) are entitled to modify centrally designed curriculum and use different educational materials.

NST is not a mandatory subject, chapter or topic in the curriculum of Greece and it is therefore not officially part of the secondary education curriculum. There have been some extra-curricular activities related to NST especially in upper-high school classes (grades 10-12, students ages 15 to 18).

Since September 2011, a new course called "The basic principles of scientific research" has been introduced in the upper high school curriculum in grades 10 and 11 (ages 15-17). Within the framework of this course, several projects related to NST were designed and implemented. The above course (duration 2 hours/week for a total of 52 weeks) provides the best platform for the introduction of NST subjects in a consistent way (theory plus laboratory activities) in the Greek secondary education curriculum.

On the other hand, some work can be done in specific units of other courses (Physics and Chemistry in energy units, Biology in cell function and drug design). Of course in

[17] Website of the Greek Ministry of Education

such a case, learning units' content and educational materials must be redesigned so that interdisciplinary in the national curriculum can be strengthened.

The learning goals can be divided into three distinct levels:

- **A. Knowledge**
  - A.1. Order of magnitude in Nanotechnology, Nanoscale, measurement techniques and instruments.
  - A.2. Radiation-matter interactions, dominant forces in the nano world, vs. dominant forces in everyday life (related to Physics courses).
  - A.3. Chemical reactions and formation of chemical bonds (related to Chemistry courses).
  - A.4. Cell function, genetic material formation (related to Biology courses).
- **B. Key competences:** skills concerning communication, group work, information processing, problem solving, critical thinking
- **C. Development of informed citizens, ethics of Nanotechnology applications**

According to the NANOPINION Teacher Coordinator for Greece, a number of measures should be taken to make sure NST can be introduced in schools the best way possible. School science laboratories must be prepared in order to be in a position to support NST learning. In addition, a library of simulation applications and other helpful educational software must be created in schools. Finally, special emphasis must be put on popularising NST for primary education teachers and pupils. But currently the national authority has not announced any plans for integrating NST-topics in the curriculum.

3.8 Israel

School attendance is mandatory and free from age 6 to 18. Formal education starts in primary school (grades 1-6, ages 6 to 12) and continues with intermediate school (grades 7-9, ages 12 to 15) and secondary school (grades 10-12, ages 15 to 18).

As defined by the Israeli Ministry of Education: *"The multi-cultural nature of Israel's society is accommodated within the framework of the education system. Accordingly, schools are divided into four groups: state schools, attended by the majority of pupils; state religious schools, which emphasize Jewish studies, tradition, and observance; Arab and Druze schools, with instruction in Arabic and special focus on Arab and Druze history, religion, and culture; and private schools, which operate under various religious and international auspices."*[18]

[18] Website of the Israeli Ministry of Education.

Compulsory Education	Age
Primary education	5-12
Middle school	12-15
High school	15-18

Table 8: Compulsory Education Israel

Most of the secondary schools are following an academic curriculum in science and humanities with the final objective for students to access the university. The Israeli school system also proposes vocational secondary schools educating technicians and practical engineers preparing for higher education, studying towards a vocational diploma, or acquiring practical skills to enter the job market directly, or to meet the needs of the Israeli army. Vocational schools propose a variety of options like librarian, mechanics, electronics, hotel trades, graphic design, etc…

The Ministry of Education is in charge of the formulation of the school curricula, the definition of educational standards, the management of the teaching staff, and building the infrastructure (school buildings). Other competences related to the education system are entitled to the local authorities. They are responsible for school maintenance and the purchase of equipment and supplies. Teaching staff from the upper secondary schools depend on the local authorities that receive their budget from the ministry according to the size of the school population and the profile of their teachers (academic and seniority). Overall, the Israeli education system is financed by public bodies (national and local) at 80 percent, while the 20% remaining budget comes from other funding bodies.[19]

The school of the Teacher Coordinator (ORT Givataym) is part of the network of ORT Israel schools, the educational network of comprehensive schools in Israel, specializing in the high-tech and science fields and in instilling knowledge, skills and values in its pupils.[20] The curriculum followed by the NANOPINION Teacher Coordinator is formulated at national scale. For each subject, the official curriculum formulates the attainment target levels and learning goals by grade. The subject's book for each grade defines a number of topics that have to be studied and known by the students. Teachers are free to choose how he/she expands up to 10% of the topics of the curriculum. This part of flexibility in the curriculum can be a space to integrate NST.

NST is not a chapter in itself in one of the scientific subjects of the Israeli curriculum but is addressed as a topic in other chapters.

There is not a defined integration of NST in the curriculum but there are several possible entry points. NST can be integrated in the Biology subject in high school grades. It should be presented in the subject of genetic engineering, genetic cure, diseases diagnostic and ecological topics. NST can also be integrated into human anatomy,

[19] Website of the Israeli Ministry of Education
[20] Website of ORT.

physiology, and micro-organisms classes with around 2-3 hours per month as a possible goal to begin with.[21]

The Teacher Coordinator additionally specifies that activities organised in class around NST should be run with audio-visual resources and include the development of projects by the students directed by scientists and engineers.

First attainment goal should focus on basic understanding of NST. A second goal would be the understanding of the size of nano elements and the specific characteristics linked to the nano-scale. Third and final goal would be to develop a creative view within NST. Teachers should encourage students to use their natural creativity within those dimension and limits.

As part of the ORT Israel school network, the Teacher Coordinator's school is offered to build a programme of NST dedicated to middle schools (grades 7-10). However, no plan to integrate NST is foreseen at national level.

The applications of NST used in NANOPINION project can be linked with the Israeli curriculum as follow:

- **Medicine and drugs using Nanotechnology** are not covered in the curriculum as such but could be linked to subject like Genetics, Genetic treatments and Engineering. Presenting new targeted medicines to cancer treatment and Nano-machines sensors used as pills can be very relevant.

- **Environment and energy**: In Israel there is a wide range of environmental projects within the curriculum starting from low grades. Every nano-based solution contributing to these issues can be easily accepted.

- **Electronics and consumers products** are very far from the subjects taught by the Israeli NANOPINION Teacher Coordinator.

[21] The places where to integrate NST mentioned by the Israeli Teacher Coordinator are all related to the Biology subject because it is her principal course.

3.9 Italy

Italy's school curricula are formulated at national level by the Ministry of Education, University and Research (Ministero dell'Istruzione, dell'Università e della Ricerca) with no regional differentiation. Education is compulsory from age 6 to 16 and covers the first cycle of education which correspond to 8 years and the first two years of the upper secondary education. The secondary school system (students aged 14-16) is based on Licei (students preparing for university) and Technical schools (Istituti).

Compulsory Education	**Age**
Scuola primaria (primary schools)	6-11
Scuola secondaria di primo grado (lower secondary school)	11-14
Seondo ciclo di instruzione (second cycle of education): • **Liceo classico** (general upper secondary school specialising in classical studies) • **Liceo scientifico** (general upper secondary school specialising in scientific studies) • **Liceo linguistico** (general upper secondary school specialising in foreign languages) • **Liceo delle scienze umane** (general upper secondary school specialising in human sciences) • **Liceo musicale e coreutico** (general upper secondary school specialising in music and dance) • **Liceo artistico** (general upper secondary school specialising in arts subjects) • **Istituto tecnico** (technical school) • **Istituto professionale** (vocational school) • **Istruzione e formazione professionale** (vocational education and training system)	14-19 Age 16-17

Table 9: Compulsory Education Italy

The *Licei* has a curriculum based on highly specialized subjects. Each *Liceo* branch has further subdivisions with a characterization for science, humanities or art and has nationally standardised curricula. In *Licei* science it is covered for the whole 5 years course and has dedicated time for ethical and societal discussions thanks to the presence of subjects like philosophy and law [22]. With regard to Science in the *Istititi* (technical and vocational school), it's mostly given in the first 2 years, except when it is also a professionally qualifying subjects.

[22] EURYPEDIA (2011b),

NST is not a mandatory subject, chapter or topic in the curriculum in the Italian secondary schools curriculum.

At this very moment the *Licei* and *Istituti* are regulated according to a reform from 2010. The first cycle of graduates will complete their education in the school year 2014-2015. The program of the new reform has neither been sufficiently defined nor have new school textbooks. According to the Italian Teacher Coordinator the unclear school program is an opportunity to fill in the "empty" space with desired topics. A lot of freedom is currently given to the teachers. The issue is whether teachers will take advantage of that or rather rely on 'old' safe curricula and habits. The degree of provided support may be crucial to push them in either direction.

In general NST fits into current science curriculum because it relies on numerous science concepts and processes which are actually part of the National science education standards. Thus NST can be integrated inside already existing traditional topics supplementing them and acting as a "fil rouge" across the curricula.

The type of activities that could be carried out with students should take form of hands on experiments and activities with systematic data collection and analysis which will fit within the Physics methodology. In Italy there is no experimental tradition, but this could be an excellent opportunity to integrate it. As a second choice computer simulations could be useful if it offers real investigation tools on real data.

It is not possible to state the hours needed per week, if the number of hours dedicated to NST is not defined a self-standing topic in a subject but rather embedded into traditional curricula in an interdisciplinary way. And optimal solution would be to have at least one or two hours per week to split between involved subjects. That would make approx. 33-66 hours per year

There are no official plans from the ministry to integrate more knowledge on NST in the *Licei* or *Istituti* systems.

There are some attempts led by universities to propose NST topics but mainly offered to selected groups of interested and excellent students. The courses are carried out at academic facilities but are not publically available. For instance:

- *Le nanotecnologie* by the Nanotech- Duesicilie school network and NNL (National Nanotechnology Laboratory) di Lecce
- *Nanotech@school* by Veneto Nanotech
- *Nanotech for students* by dipartimento di scienze dei materiali dell'Università degli studi di Milano-Bicocca
- The Physics Department of Modena and Reggio E. University together with CNR Nano has developed a new initiative aimed at including nano-inspired hands-on activities in high schools

- *NANOLAB* is an open project whose resources are published under Creative Commons license in an open website www.nanolab.unimore.it

A first national teachers coaching course was held in autumn 2011 in Modena and a new national one will take place in 9-12 September 2013.

The applications of NST used in NANOPINION project can be linked with the Italian curriculum as follow:

- **Medicine and drugs using nanotechnology** are not covered by the curriculum. Biology (cell, human body) curriculum in the first years of all types of secondary schools is a good entry point to teach this application of Nanotechnology

- **Environment and energy and natural Nanomaterials** are issues covered as subtopic in one of the science courses. Nano applications used in environment and energy can be approached in various subjects, namely: Physics, Biology, Earth Science, and Chemistry in the first years of all types of schools. It can then be delved deeper in 5th year in the Physics and Chemistry courses possibly working together

- **Electronics and sensors made with nanotechnology** are not applications that are covered by the curriculum. They can however be related to Physics and Chemistry at 5th year level

- **Consumers products based on nanotechnologies** are not applications that are covered by the curriculum but could be approached at all science subjects in all schools early years.

1.1

3.10 Lithuania

The Ministry of Education and Science is responsible for the development and implementation of compulsory education policies. According to the law, children start compulsory education at the calendar year when they turn 7 years of age and ends when they reach the age of 16. [23]

Compulsory Education	Age
Mokykla-darželis (pre-primary and primary education)	7–10/11
Pradinė mokyla (primary education)	7-10/11
Pagrindinė mokyla (general lower secondary education)	10/11-16
Vidurinė mokykla (secondary education)	7-16
Gimnazija (general lower secondary education)	14/15-16
Profesinė mokykla (vocational lower secondary education)	14-16
Jaunimo mokykla (general lower secondary education)	11/12-16

Table 10: Compulsory Education Lithuania

NST is not a mandatory subject, chapter or topic in the curriculum of Lithuania and the general school programs are nationally standardised with well defined topics and chapters. The content, timing, textbooks and other material are optimal for each teacher and they have some possibility to change the general curriculum corresponding to 10%.

Even though NST is not mandatory it is still mentioned as a very small part of the curriculum that teachers can take up on their own initiative. Students are given a basic knowledge of the subject, which makes them capable of explaining what NST are and give examples of nanoproducts. This means it is possible to create modules about nanotechnology as long as they are in line with the general defined topic and chapters of the nationally defined curriculum.

There exists a big national project on mostly biotechnology, in Lithuania called '*The creation of the system of science teachers competencies lifting up in the biotechnology field*' [24]. The aim is to create one module which can be chosen by children interested in biotechnology. The project provides educational and some changes are made in the

[23] EURYPEDIA (2011c)

[24] Original name: *Gamtos mokslų mokytojų kompetencijų biotechnologijų srityje kėlimo sistemos sukūrimas*, see more on: http://www.esparama.lt/paraiska?id=30912&pgsz=10 and http://mparkas.lt/media/user_files/root_folder/Projektai/Info_apie_projekta_2.pdf

curriculum. In this module also nanotechnologies will be mentioned but from a bio technological perspective.

The Ministry of Education and Science has not mentioned plans about integrating more NST into the curriculum. But in general the teachers are encouraged to introduce students to NST at all levels.

As the system if quite flexible NST can be integrated in national curriculum if:

1. a program of nanotechnology modules is created;
2. the educational materials (teacher and student books, exercises, different problems to solve, experiments) are provided in Lithuanian language;
3. training for the teachers are organised;
4. the module are used by several pilot schools.

Medicine & drugs using Nanotechnology are not applications that are covered by the curriculum.

Environment & energy Natural Nanomaterials are covered as a subtopic in one of the science courses. This is a subtopic of Physics (grade 11-12) on electronics. It is also possible to integrate the topic in Chemistry lessons.

Electronics & sensors made with Nanotechnology are not applications that are covered by the curriculum.

Consumers products based on Nanotechnologies are not applications that are covered by the curriculum.

3.11 Romania

The Romanian Educational System is regulated nationally by the Ministry of Education, Research, Youth and Sports. All schools have the opportunity to include some optional courses on request from beneficiaries of education (parents, children, community), this kind of curriculum is called curriculum by school decision and it's approved by the administration team of the school for a short period (minimum one scholastic year). This means that the Romanians schools have some level of local autonomy to adjust the curriculum to special interest of its beneficiaries.

Compulsory Education	**Age**
***Şcoala primară* (primary level), ISCED I**	6-10
Gimnaziul (first phase of lower general secondary level), ISCED 2	10-14
***Liceul – ciclul inferior* (second phase of lower general or specialised secondary level), ISCED 2** **or** ***Şcoala de Arte şi Meserii* (lower vocational secondary level – is being in liquidation from the 2009/10 school year), ISCED 2 & Level 1 of Vocational Qualification**	14-16

Table 11: Compulsory Education Romania

Compulsory education lasts 10 years (student aged 6 -16). Students aged 12 to 14 belong to the last two years of first phase of lower secondary education for which the curriculum is nationally standardised. NST could be integrated in the Chemistry curriculum (13-14 years) which has an obligatory chapter about atoms, ions, molecules (only introductory explanations/ notions).

The second phase of lower secondary education (Gymnasium) provides general, specialised or vocational courses (students aged 14 to 16 years). At this stage, the curriculum contains an advanced chapter about atoms and their structure, ionic compounds, molecules (polar and non-polar), ionic and molecules networks, complexes which could be well combined with nanotechnology examples.[25]

NST is not a chapter in the science curriculum (Chemistry, Biology or Physics) in Romania. As NST is a very new science, the majority of science teachers do not have basic knowledge about the subject to be able to teach it. The Romanian Ministry of Education, Research, Youth and Sports nor teacher training centres for professional development organises courses in this field.

Teachers who participated in the Nanoyou project[26] developed some nanotechnology dissemination activities in their local communities: experiments with nanotex, theoretical sessions, and computer games. Some of these teachers developed courses based on the curriculum on the school decision principle, a strategy that can be reused for the NANOPINION project. This procedure guaranties paid work for teachers who set up a modified curriculum, usually for 1 hour per week, corresponding to 35 hours per year. A curriculum provided on this basis must be approved by the principal of the school and the Regional Inspectorate of the County (a structure of the Ministry of Education). The hours are included in the obligatory hours for students.

A second possibility for integrating more NST knowledge among school students is through extra curricula activities (science clubs during the weekend or after school). This is a voluntary work. Any teacher can make their own curriculum, to help improve the students' performances. The schedule is flexible and sometimes the teacher can have an activity for 1 to 2 hours, sometimes more, it depends on the complexity of the lesson. But as this is extra curricula activities, this option should only be used as additional approach to integrating more NST knowledge among Romanian school students.

The applications of NST used in NANOPINION project can be linked with the Romanian curriculum as follow:

- **Medicine & drugs using nanotechnology** are not applications that are covered by the curriculum. It could be introduced for students by forming an introductory chapter explaining the basic principles of the nanotechnology science. It could contain information about the most simple notions, definitions, nano scale, and examples of nano-applications in life (medicine, pharmacy, clothes industry, cosmetics etc.).

[25] EURYPEDIA (2011d)
[26] http://nanoyou.eu/

- **Environment, energy and natural Nanomaterials** are not applications that are covered by the curriculum.

- **Electronics & sensors made with nanotechnology** are not applications that are covered by the curriculum.

- **Consumers products based on nanotechnologies** are not applications that are covered by the curriculum. But it could be introduces on by giving some examples on super-hydrophobic materials.

3.12 Spain

Spain has a decentralised education system, which distributes the education responsibilities among the State, the Autonomous Communities, local Authorities and schools.

The Ministry of Education sets the general organisation of the education system on the basis of minimum requirements for schools, minimum core curriculum and international cooperation in education.

The Autonomous Communities (17 regions) have an administrative responsibility within their territories of schools' creation and management, as well as their new development of syllabuses and regulation of levels, branches, grades and specialisations, education inspection, supervision of textbooks and other curriculum-related materials.

The Spanish local authorities (province within regions) are set for building public schools, planning extra-curricular and supplementary activities, monitoring compulsory schooling, creation of School Councils within their municipality. [27]

Compulsory Education	**Age**
***EducaciónSecundaria Obligatoria*, ESO (Lower Secondary Education)**	12-16
NB: Non compulsory - general upper secondary education: • ***Bachillerato (university preparation)*** • ***Ciclos formativos de grado medio* (Intermediate Vocational Training)** • **Enseñanzas profesionales de régimen especial (Intermdiate vocational specialised education)**	Approximately 16-18

Table 12: Compulsory Education Spain

Students aged 12 to 16 are attending the last years of secondary school forming part of the national compulsory education. At this level NST is not a mandatory subject, chapter or topic. Students in the last years of secondary school follows a well-defined curriculum, but teachers have the possibility to make some changes and this way integrate some short examples and experiments on Nanotechnology.

Students aged 16 enter the first year of the *Bachillerato* (see table 10) which is not a compulsory education. At this level, the curriculum is more strictly defined since students have to acquire a certain level in order to pass an admission exam for

[27] EURYPEDIA (2011e)

university. NST is addressed as a topic in the first year of high school in chapters of a compulsory subject named *Sciences for the contemporary world*. The subject is flexible and holds various possibilities for integrating NST related lessons (the Nanoyou project was for example integrated within this subject). The subject aims to foster understanding of the importance of science in the society among the students and it has the purpose to give the students a basic knowledge of science which can help them read information and news about science from a critical and objective perspective.

Science for the Contemporary World is given 2 hours per week, under which NST is compulsory 8 hours per year (excluding homework assignments). ICT is easily integrated, since most of the curriculum foster activities linked to new technologies. The purpose of the subject is to give the students a notion on the cutting edge of scientific research. One of the main objectives of the subject is to make students discuss about scientific knowledge of social interest relative to materials (among others) so that students can evaluate critically what they read in newspapers or see on TV from a more objective perspective. Depending on the teacher there is flexibility to integrate more hours of NST content with workshops for example. The curriculum is sufficiently vague as to give the students as much info as teachers find it suitable. The nano-activities could be carried out in groups as the curriculum of this subject also fosters group collaboration and use of ICT in education. It is even possible to make use of laboratories if needed for experiments.

There are some uncertainties about the future of the *Science for the Contemporary World* subject in the curriculum. An educational reform is to be defined for next school year. [28]

Additionally, the Catalonian region has a resource centre (CDEC) for schools that provides material for nanotechnology-related experiments. [29]

The applications of NST used in NANOPINION project can be linked with the Spanish curriculum as follow:

- **Medicine and drugs using nanotechnology** are covered as a subtopic in one of the science courses
- **Environment and energy using nanotechnology** are covered as a subtopic in one of the science courses. It is mentioned as new technologies, such as Nanotechnology, to solve increasingly complex problems
- **Electronics and sensors made with nanotechnology** are covered as a subtopic in one of the science courses.
- **Consumers products based on nanotechnologies** are covered as a subtopic in one of the science courses. In the contents of the subject there is a clear reference to new needs and new materials. Solutions offered by science and technology to

[28] http://www.xtec.cat/alfresco/d/d/workspace/SpacesStore/cb9e9447-316c-4d63-a80e-249c948303df/ciencies_mon_contemporani.pdf

[29] http://phobos.xtec.cat/cdec/index.php?option=com_content&view=article&id=17&Itemid=105

achieve new materials such as polymers, thermoplastic and, structural, hybrid or recyclable materials.

3.13 Turkey

In Turkey, primary and secondary school are part of the compulsory education. The Ministry of National Education is responsible for preparing curriculum, maintaining coordination between educational institutions and construction of school buildings for the compulsory education of Turkey. [30]

Since 2012 Turkey has a 12 years compulsory education system enclosing ages 6 to 18. Primary school lasts 8 years (students aged 6-14) while secondary education lasts 3-4 years (students aged 14-18) and includes all the general, vocational and technical education institutions.

Compulsory Education		**Age**
Primary School *(İlköğretim Okulu)*	Grade 1 – 8	6 – 14
Vocational and Technical Secondary Education: • **Technical and Industrial Vocational Schools *(Teknik Lise ve Endüstri Meslek Lisesi)*** • **Technical and Industrial Vocational Schools for Girls (*Kı z Teknik ve Meslek Lisesi)*** • **Hotel and Tourism Vocational High School (*Otelcilik veTurizm Meslek Lisesi)*** • **Business High School *(Ticaret Meslek Lisesi)*** • **Health Vocational High School) *(Sağlı Meslek Lisesi)*** • **Special Education Vocational Schools *(Özel Eğitim MeslekLisesi)***		14-18

Table 13: Compulsory Education Turkey

NST is not a mandatory subject, chapter or topic in the curriculum at any level in Turkey's compulsory education curriculum however, NST can be integrated in the Turkish curriculum in various ways. In the first year of secondary education, (students aged 14-15) the Chemistry subject contains a chapter about matter and its properties goals and the changes in the properties of matter at nano scale. This would give students an understanding of the magnetic property of nano-materials and elements as well as different surface area of nano-materials. The time spent for this chapter is 3 lessons of 40 minutes in a school year.

The same school year the Chemistry subject also has a chapter about atomic models introducing students to modern atomic theory. Here the students could be taught about the difference in the Physics rules of macro and nano sizes, and the relation between quantum model of atom and Nanotechnology. The time spent for its chapter is one lesson of 40 minutes of the school year. The Chemistry chapter of the same year called "*Our lives"* could hold lessons about the effect of nanoscience and technology in our lives. Time spend for this chapter is 2 lessons of 40 minutes.

[30] EURYPEDIA (2011f)

During the second year of secondary education (students aged 15-16) the Chemistry chapter on chemical synthesis and reaction rate could hold information about synthesis of Nanomaterials and the difference between the reaction rates of nano-particles and macro particles. Time spent for this chapter is 2 lessons of 40 minutes of a school year.

During the 3 year of the secondary education (students aged 16-17) one Chemistry chapter focuses on thermo Chemistry. It is possible to focus on the advantages of using nano-materials for the storage of energy. The time spent for this chapter is 1 lesson of 40 minutes.

The national curriculum changes every year but the changes happen only within a certain topics and chapters. The curriculum has not contained any nanotechnology subjects previously.

In Turkey, some of the schools have an extra preparation year before secondary education (students aged 14-15) where students have a science courses which covers Chemistry, Biology and Physics. Most beginner level materials of nano-science activities can easily be integrated into this year since there the subject contains no predefined curriculum.

- **Medicine and drugs using nanotechnology** are not covered as a subtopic in one of the science courses. But in general the topic can be mentioned both in Chemistry and Biology. In Chemistry synthesis of gold coated particles and the use of these particles in drug delivery can be explained in chemical synthesis chapter. Also a more interdisciplinary approach can be made by explaining the anti-bacterial property of these particles. In Biology classes the affect of gold coated particles on bacterial samples and in cells could be tested.

- **Environment and energy using nanotechnology** are covered as a subtopic in one of the science courses. Environment and energy can be combined with electronics and sensor made with nanotechnology, for example in the curriculum of the third year of the secondary education year in the Physics classes. Here teachers may mention photovoltaic cells and the advantages of using nano-materials in this field.

- **Electronics and sensors made with nanotechnology are** not covered as a subtopic in one of the science courses.

- **Consumers products based on nanotechnologies** are not covered as a subtopic in one of the science courses. Consumer products based on nanotechnologies can be best fitted into first year of secondary school in the Chemistry subject in the chapter called *'Our lives'.* Here at least 2 lessons of 40 minutes can be spent to explain the use and advantages of nano-materials in our lives.

4. Mapping curriculum and creating clusters

The previous section presented 13 country profiles on NST in the curriculum for Bulgaria, Croatia, Denmark, Czech Republic, Finland, Germany (Bavaria), Greece, Israel, Italy, Lithuania, Romania, Spain (Catalonia and Asturias) and Turkey. In this section, we aim to group the countries according to the flexibility of the school systems and of the curriculum.

For each of those countries, a Teacher Coordinator was selected to act as ambassador of the project and fulfil a number of activities in class and in an expended network of schools.

The mapping exercise has the final aim to group EU Member States and associated countries involved in the NANOPINION project according to how NST topics can be incorporated into their local curricula. We suggest some clusters of European countries to tailor how to use the NANOPINION platform and the trainings for each country.

This exercise is done for the need of the project, for the organisation of outreach and dialogue activities in Formal and education settings. The overall purpose of this exercise is not the classification of curriculum in itself but the clustering of countries to better adapt the offer of educational services to schools.

We propose to cluster the curriculum according to a main criterion, **the flexibility of the curriculum**. We envisage the possibility to integrate a new topic in the curriculum depending on the autonomy of regional and local authorities or schools and teachers, the way teaching time is allocated, the place given to the flexible timetable of the curriculum, the regulatory level and planned reforms.

After clustering the various curricula of countries and regions involved in the project, we also analyse in detail the possibilities to integrate NST topics in 13 curricula. We provide an overview of the levels and subjects where NST topics can be integrated in these various school programmes.

4.1 NANOPINION clusters of countries

The NANOPINION project aims to contribute to the improvement of upper secondary education system to better prepare young students to employers needs and the general development of European growth and sustainability. This way the project is in line with the study carried out by Dr. Pasi Sahlberg, for the European Training Foundation: "*Policymakers need to be aware of different alternatives in order to have a responsive and flexible upper secondary education system that simultaneously serves the needs of employers and lifelong learning".*[31]

In this context the flexibility of the curriculum was chosen as a criterion to create clusters of countries because this characteristic will define specific strategies to

[31] Sahlberg, Pasi, (2007),

integrate NST in the school programme and help foresee in which countries the NANOPINION project might meet challenges when trying to integrating school courses on NST. The flexibility criterion is particularly relevant when assessing and mapping clusters as it is a key element to determinate different strategies to achieve better quality secondary education in highly differentiated national contexts.

In our analysis, by flexibility we refer to several dimensions including the possibility to **integrate new topics**, the **autonomy of regional and local authorities or schools and teachers** to determine their programme.

The most common reasons to decentralise decision in education systems are to increase the efficiency and the financial control, reduce the administrational costs, and better involve communities. Finally, decentralisation enables more potential for innovation and improved quality of schooling.[32] We therefore take this indicator positive as a criterion which can facilitate the inclusion of new scientific topics in the curriculum.

Another dimension is how different countries and regions give space to the **flexible timetable of the curriculum.** This part of the curriculum appears to be a right entry point to teach ELSA aspects of NST for example and even the scientific aspects of the topics since, most of the time it allows increasing time for particular educational areas and fields.

The flexible timetable of the curriculum can be defined as: "*the part of the curriculum that can be devoted to various subjects selected by the school or the student but still included in the total compulsory time for student instruction*." [33]

For example, in Czech Republic, the Eurydice study explains that this part of the curriculum is dedicated to cross-curricular topics such as social education, citizenship, European and Global education, environmental studies etc. It is also the part of the programme to allow teachers to expand the time allocated to particular educational domains and include additional education fields and optional content.[34]

To form these clusters, we also took the **regulatory level of the curricula into account**. The science education system of the 13 countries and regions part of NANOPINION are all regulated at national level. Some countries give space to further adjustments of the regulations on a regional or local level and sometimes to the own appreciation of the teacher. Finally, we consider the plans public authorities have to **reform** the curriculum and include NST.

The NANOPINION platform and resources should be designed taking as much as possible these characteristics and strategies into account.

[32] UNESCO-IBE (2012),
[33] Eurydice study (2009/10).
[34] Eurydice study, 2009-2010, Idem

4.1.1 Group 1 - Countries or regions with very flexible curriculum & provision of education

This group of countries includes Denmark, Finland, Israel, Italy and Spain (Catalonia and Asturias).

Denmark

All Primary and Lower Secondary schools are following common regulations in Denmark but teachers have quite an extensive freedom to adapt to the local characteristics. The autonomy of schools in Denmark is quite wide, they are self-governing institutions with various historical and academic backgrounds. The headmasters report to a board formed by representatives selected in function of the specificity of the school profile. The representatives seating at the school board are appointed by the teachers and students of each schools. This board is in charge of the overall management of the school and its activities. This includes hiring and dismissing the headteacher. The boards are reporting to the Ministry of Education with an annual quality report that present the school system, the academic level, measures taken for the evaluation of the academic level, and progress since latest report. [35] Apart of the main core subject matters set by the Danish Ministry of Education, teachers have freedom to choose methods and teaching materials according to individual preferences and school policies. [36]

Finland

The Finnish secondary education system and curriculum is a good example of flexibility even if the government as a key role in defining its content and objectives. The municipalities have the autonomy to adjust the curriculum to local preferences and needs of their schools. Many matters are decided by the education and training providers themselves, the local authorities and their consortia. Pre-primary and basic education and upper secondary general and vocational education are however governed by objectives set in legislation and by national core curricula.

As explained by Dr. Pasi Sahlberg in the paper for the European Training Foundation: "*The development of the current secondary education system in Finland is a result of systematic improvement of quality, access, efficiency and flexibility of, not only secondary education but the entire education system as a whole*".[37]

This is confirmed in an article from the Guardian on the Finish schools from December 2010, "S*tate prescribes the curriculum but leaves teachers alone to decide how to teach the subject*".[38] This article further analyse the school system explaining that it contains a great flexibility in terms of how students define their timetables combined with a relative rigid approach to the curriculum. Teachers are free to interpret the subjects as

[35] Website of the Danish Ministry of Education
[36] Website of the Danish Union of Teachers
[37] Sahlberg, Pasi, (2007),.
[38] Vasagar, Jeevan (5 December 2010).

they decide but they have to follow the list of compulsory subjects prescribed by the government.

The flexible place given to the teachers allows them to use the methodology they prefer and approach new scientific disciplines and concepts.

Israel

In Israel, The Ministry of Education is in charge of the formulation of the school curricula, the definition of educational standards and the management of the teaching staff. Other competences related to the education system are entitled to the local authorities, responsible for school maintenance and the purchase of equipment and supplies. Teaching staff from the upper secondary schools depend on the local authorities that receive their budget from the ministry.

Apart of the main core subject matters that each Israeli student must learn (Mathematics, English, History, Civics, Bible, Literature, Hebrew) The Ministry of Education in Israel is flexible regarding the application of the curriculum by teachers at local level. It fosters school autonomy with the objective to improve the quality of education at school level. The Ministry consider that teachers have better premises for developing and formalising an educational approach leading to a curriculum adapted to school and local specificities. [39]

Italy

In Italy, teachers benefits from a great flexibility in the application of the curriculum. The programme of the latest reform implemented in Italy has been defined in a broad way and was not accompanied to the publication of new school textbooks. As reported by the NANOPINION Teacher Coordinator, the widely defined school programme is an opportunity for teachers to integrate new topics. A lot of freedom is currently given to the teachers in that context. A good strategy to integrate NST in Italian secondary schools is to encourage teachers to take advantage of this freedom. The degree of provided support may be crucial to motivate them.

Spain (Catalonia and Asturias)

In Spain, the flexibility of the curriculum we have identified remains in the autonomy of regional authority towards the official curriculum formulated at national level and in the scientific school programme. The compulsory subject named "Sciences for the contemporary world" is flexible and holds various possibilities for integrating new scientific disciplines and applications. The subject fits really well with NST as it aims to foster understanding of the importance of science in the society among the students. It also has the purpose to give the students a basic knowledge of science which can help them read information and news about science from a critical and objective perspective. The curriculum is sufficiently open as to give the students as much info as teachers find it suitable.

[39] UNESCO-IBE (2012). -

4.1.2 Group 2 - Countries or regions with flexible curriculum & provision of education

The second group of countries includes Bulgaria, Czech Republic, Germany (Bavaria), Lithuania and Romania

Bulgaria

Bulgarian curriculum at secondary level is quite flexible, although each subject is regulated at a national level each teacher has flexibility to shape the curriculum on an individual basis. The individual curriculums are approved by the School Director to ensure it live up to the national curriculum requirements.

Croatia

Some legislative changes initiate in 2000 in Croatia have led to a relative autonomy of cities, counties and schools for the primary and secondary education. The Croatian secondary education benefits from decentralisation of funding and management enabling to include local self-governance bodies overall resulting in greater schools and teacher autonomy. [40]

There are no signs of new initiatives to integrate more knowledge on NST in the national curriculum in a near future but schools generally seem open to any extracurricular activities in science and NST.

Czech Republic

In the Czech Republic, the headteacher has the full responsibility for the quality of the educational process, the financial management of the school, appointing and dismissing teachers and relations with the community and the public. The school organising bodies have the legal obligation to establish a School Council to enable parents, pupils, staff, and the public to participate to the administration of the school. This means that the educational system has a certain level of local autonomy toward the general national objectives.

In Czech Republic, decision is most often taken at the school level. According to the OECD Indicators of 2012, 68% of decisions are taken by the schools while only 32% by other authority levels. [41]

Germany (Bavaria)

There is no national curriculum in Germany, the duty for education remains at the Länder level. This structure leaves a very wide autonomy to the Länder, however, a common national educational standards to be achieved at primary and secondary levels was put in place in 2002 by the Ministry of Education and Culture for the 16 Länder.

[40] UNESCO-IBE (2010/11).
[41] OECD (2012), idem, p501

In this report, we look at the Bavarian curriculum as the NANOPINION Teacher Coordinator for Germany is based in this Länder and will implement the project there. The fact that the region is responsible for the content of the curriculum gives a relative flexibility to the programme but Bavaria has quite a conservative approach compared to other Länder.[42]

The scientific curriculum allows quite some flexibility to define content and new approaches as an addition to the core part of the compulsory curriculum, students can choose to have more STEM lessons from form 8 to form 12 (13 to 18 years old). In these additional lessons the curriculum only offers proposals to the teachers. Teachers are quite free to choose subjects. This is a perfect way to test and prepare a NST curriculum for the next update. In this special science option, there is an additional lesson in Physics and one in Chemistry each week. NST all year long is not possible due to the current structure of the curriculum but half a year would be feasible.

Lithuania

The choice of content, timing, textbooks and other material are given to teachers but they have some possibility to change the general curriculum up to 10%.

Even though NST is not mandatory it is still mentioned as a very small part of the curriculum that teachers can take up on their own initiative. Students are given a basic knowledge of the subject, which makes them capable of explaining what NST are and give examples of nano-products. It is possible to create modules about NST as long as they are in line with the general defined topic and chapters of the nationally defined curriculum.

A wide national project is under way, focussing mostly on biotechnology. The aim is to create one module that can be chosen by children interested in biotechnology. The project will cause some changes in the curriculum. In this module NST will be mentioned from a biotechnological perspective.

The Ministry of Education and Science has not mentioned plans about integrating more NST into the curriculum but in general the teachers are encouraged to introduce students to NST at all levels.

Romania

Despite a relative rigidity of the curriculum in Romania, the possibility exists for teachers to develop courses based on the main curriculum on the school decision principle, a good strategy to include new topics in the programme.

A second possibility for integrating more NST knowledge is to develop extra curricula activities (science clubs during the weekend or after school) on the basis of voluntary work of teachers. Any teacher can make their own curriculum, to help improve the students' performances. The schedule is flexible and sometimes the teacher can have an activity for 1 to 2 hours, sometimes more, it depends on the complexity of the lesson.

[42] Eurydice at NFER, Unit for England, Wales and Northern Ireland (2010/09), p13

But as this is extra curricula activities, this option should only be used as additional approach to integrating more NST knowledge among Romanian school students.

4.1.3 Group 3 - Countries or regions with less flexible curriculum & provision of education

Greece

In Greece, the curriculum for all secondary education schools are formulated at national level by the Ministry of Education, and all schools use the same set of course books and supplementary material. An exception to this low level of flexibility is the specific type of schools called model schools, the school type 3d (see section 3.7 Greece) that are entitled to modify centrally designed curriculum and use different educational materials. These schools have the mission to design, implement and validate educational innovations and appear to be perfect to test the inclusion of NST in the curriculum.

According to the OECD Indicators of 2012, the decision making in the Greek educational system is one of the most centralised with 78% of decision taken at the central state level. [43]

Turkey

Even though Turkey gives a relative important place to the school autonomy in terms of instruction organisation, current researches confirm that the teachers do not have flexibility to regulate the contents of the school programmes and the special needs and circumstances of the class into account. According to the research carried out by İbrahim Hakkı Öztürk, this structure of the educational system has an impact on the attitudes and practices of teachers toward the development and organisation of the curriculum. The reform introduced in Turkey in 2000 has not enabled to increase the autonomy of teachers for the choice of teaching content, methods and materials.[44]

4.1.4 Comparisons on flexibility of educational systems across European countries

In this section we complement the analysis provided above that served to form clusters of countries for the needs of the NANOPINION project with some comparisons made with the use of indicators on different aspects of the flexibility of educational systems across European countries.

The chart below from the OECD report, Education at a Glance 2012: OECD Indicators provides the percentage of decisions taken at each level of government in public lower education for the organisation of the instruction. It shows that Greece gives the smaller proportion to school decision and has a much centralised education system, while Turkey shared the decision taking with 50% taken at schools level and 50% at state and

[43] OECD (2012), idem, p501
[44] İbrahim Hakkı Öztürk (2011),

regional level. Israel gives an important space to schools to take decision related to the organisation of the instruction. Czech Republic (100%) and Germany (80%) also gives an important role to schools to organise the instructions in lower secondary education.

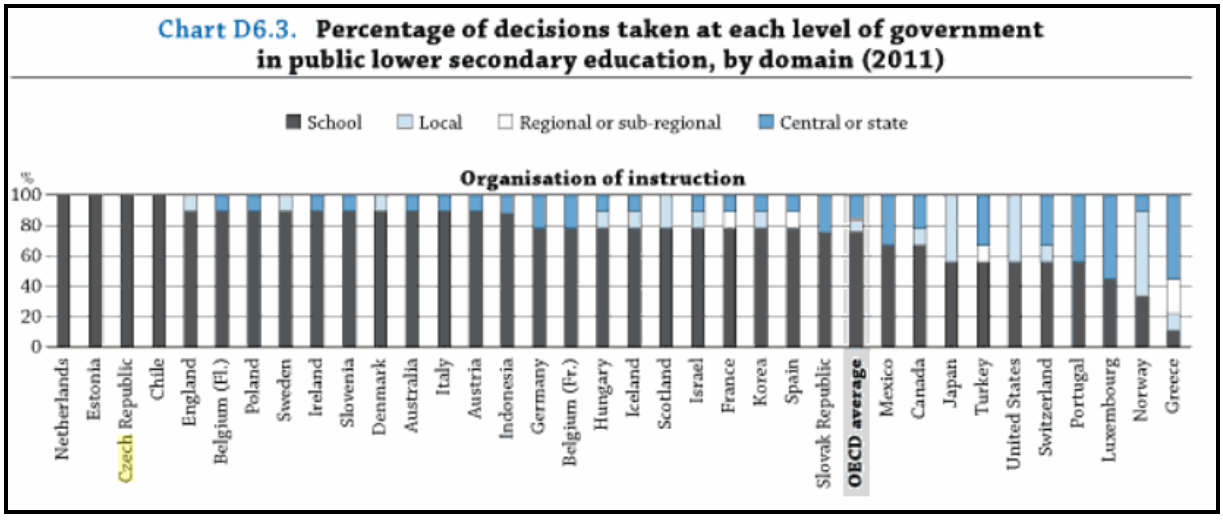


Figure 2 Percentage of decisions taken at each level of government in public lower education for the organisation of the instruction[45]

As shown in figure 3 below, the Eurydice report providing key data on Education in Europe of 2012 provides interesting information on the autonomy of schools for teaching and learning in primary and general (lower and upper) secondary education.

In figure 3, 'No autonomy' means that decisions are taken only by the education authority, although the school may be consulted at a particular stage of the process.

'Full autonomy' means that the school alone takes decisions, within the limits set by national/local legislation or regulations. Guidelines can nevertheless be provided by the education authority but they do not restrict school autonomy.

'Limited autonomy' comprises four different situations:

- schools take decisions together with the education authority or submit proposals for approval;
- schools take decisions based on a set of options predetermined by the education authority;
- schools have some autonomy in the area concerned but, as far as the remainder of decisions are concerned, must refer to the education authority or is not autonomous;
- schools are autonomous in principle but are strongly encouraged to follow official recommendations.

[45] OECD (2012), idem, p501

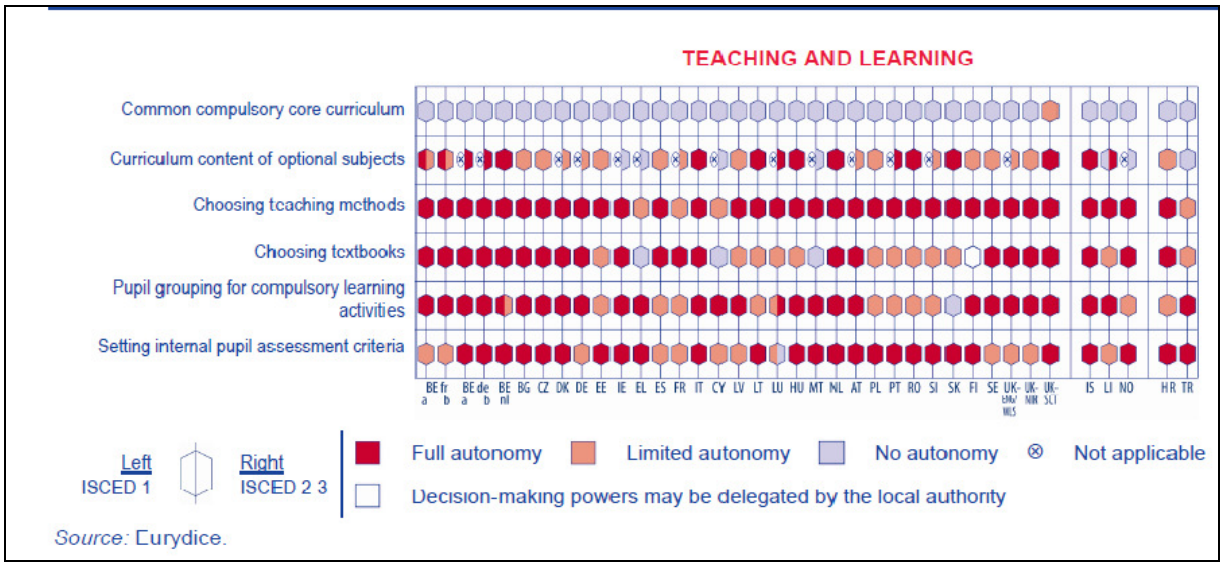


Figure 3 Levels of school autonomy for managing aspects of teaching and learning in primary and general (lower and upper) secondary education (ISCED 1-3), 2010/11[46]

The figure 3 shows that schools from the countries from **group 1** (most flexible: DK, FI, IL, IT and ES) have full autonomy on 4 to 5 of the criteria used by Eurydice to evaluate the autonomy for managing aspects of teaching and learning in primary and general secondary education. Spain is the exception as its schools have full autonomy only in choosing teaching methods and the textbooks. Spain remains however in group 1 has its educational system gives a large space (80%) to the schools regarding the decisions taking process for the organisation of the instruction (see figure 2) and has a special subject allowing the integration of new scientific topics. Italy is the country were schools have the higher level of autonomy in our first group, one of few countries where the curriculum content of the optional subjects is left to the full appreciation of schools.

Figure 3 also shows that countries from **group 2** (flexible: BG, CZ, DE, HR, LT and RO) have full autonomy for 3 to 4 of the criteria used to define the schools autonomy in terms of teaching and learning aspects. Bulgaria and the Czech Republic are the countries from group 2 that leave the most autonomy to their schools. They have full autonomy to choose teaching methods and the textbooks, the pupil grouping for compulsory learning activities and finally the setting of internal pupil assessment criteria. Lithuania and Romania have similar indicators, their schools have full autonomy for the definition of the curriculum content of the optional subjects, choosing the teaching method and the setting of internal pupil assessment criteria. Finally, schools of Germany are fully autonomous to choose the teaching methods and the textbooks as well as for the pupil grouping for compulsory learning activities but have a limited autonomy for the definition of the curriculum content of the optional subjects and for the setting of internal pupil assessment criteria.

Finally, figure 3 illustrates that schools of the countries from **group 3** (less flexible: EL and TK) have full autonomy for 2 of the criteria used to define the schools autonomy in terms of teaching and learning aspects. Greek schools have no autonomy to define the curriculum content of the optional subjects and to choose the textbooks and limited

[46] EACEA; Eurydice; Eurostat (2012), p50

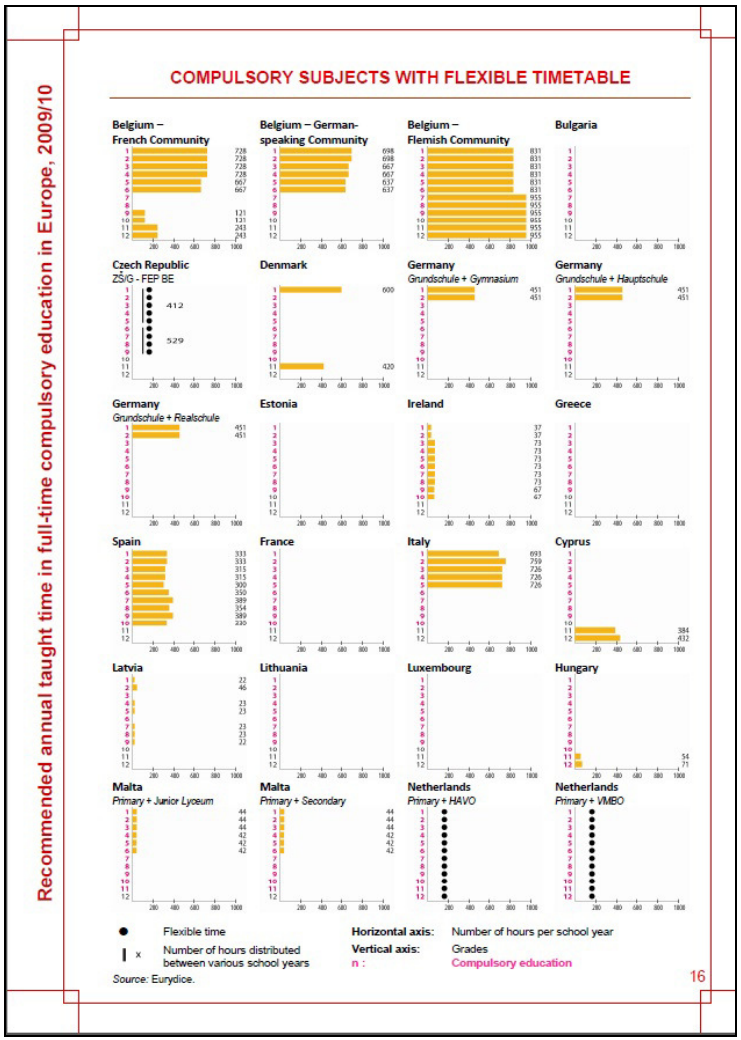
autonomy to choose the teaching methods. They have however full autonomy for the setting of internal pupil assessment criteria and the pupil grouping for compulsory learning activities. In Turkey, schools are not autonomous to outline the curriculum content of the optional subjects and have limited independence to choose the textbooks and teaching methods. Their full autonomy lies in the setting of internal pupil assessment criteria and the pupil grouping for compulsory learning activities.

None of the 13 countries involved in the NANOPINION project have a full autonomy to define the common compulsory core curriculum.

Figure 4 below shows the taught time dedicated to compulsory subjects in the curriculum with flexible timetable, time that can be well suited to integrate new topics.

As highlighted above it is a part of the curriculum that represents a good place to teach ELSA aspects of NST for example and even the scientific aspects of the topics since, most of the time it enable teachers to dedicate more time for particular educational areas and fields they want to go more into in depth.[47] The number of hours dedicated to the compulsory subjects in the curriculum with flexible timetable is reported in table 12 to allow comparison between the countries taking part to NANOPINION project and explain better the clusters defined for the needs of the project.

[47] Eurydice study (2009/10).



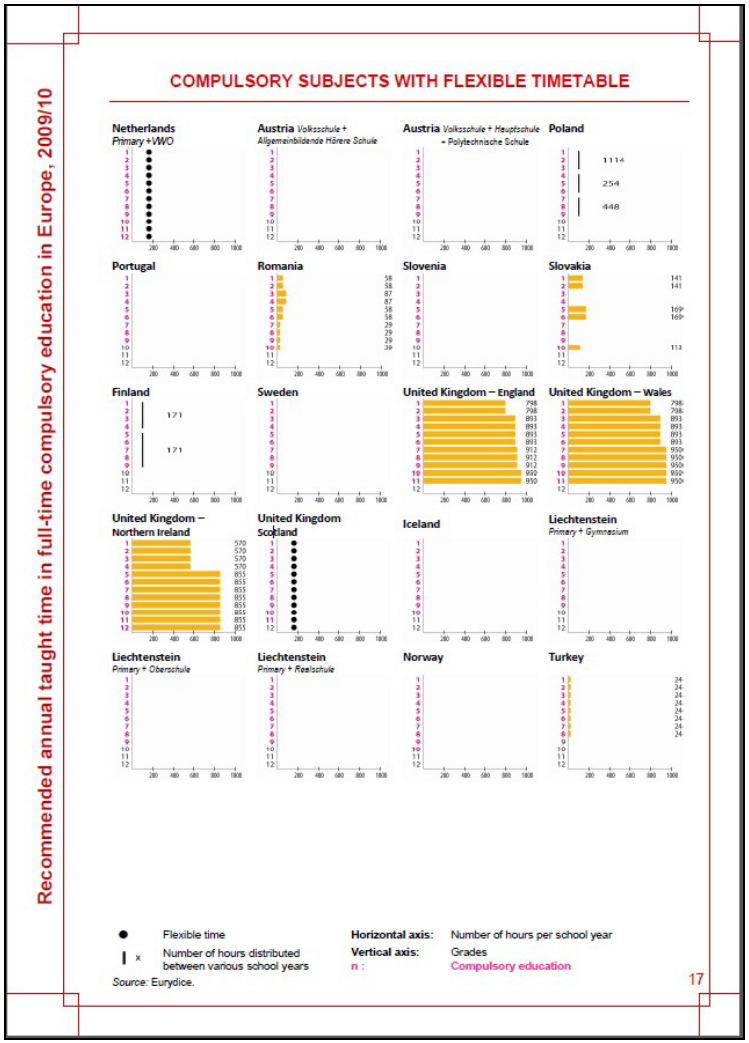


Figure 4 – Taught time for compulsory subjects of the curriculum with flexible timetable in Europe – Eurydice 2009/10

4.1.5 Overview of NANOPINION clusters:

This table provide an overview of the indicators chosen linked to flexibility allowing comparison between the countries taking part to NANOPINION project and explain further the clusters defined for the needs of the NANOPINION project.

Groups	Country	Number of criteria for which primary and general secondary education schools have full autonomy (see figure 3)	Percentage of decision made by schools for organisation of instruction (see figure 2)	Space given to compulsory subjects with flexible timetable in secondary education (12 – 18 years old students) [48]	Regulatory level of the curriculum
Group 1 Countries or regions with **very flexible** curriculum & provision of education	DK	4	85%	420 hours	Schools are self-governing institutions; Representatives seating at the school board are appointed by the teachers and students of each schools
	FI	4	n/a	171 hours	Municipalities have the autonomy to adjust the curriculum to local preferences and needs of their schools.
	IL	4	79%	n/a	Apart of the main core subject matters, the MoE is flexible regarding the application of the curriculum by teachers at local level.
	IT	5	90%	0 hours	The programme of the latest reform was not defined in a broad way and lots of freedom is currently given to the teachers

[48] Eurydice study (2009/10).

	SP*	2	80%	1463 hours	Autonomy of regional authority towards the official national curriculum
Group 2 Countries or regions with **flexible** curriculum & provision of education	BG	4	n/a	0 hour	Each teacher has flexibility to shape the curriculum on an individual basis. Individual curriculums are approved by the School Director
	CZ	4	100%.	529 hours	The Headteacher has the full responsibility for the quality of the educational process, management of the school & appointing and dismissing teachers
	HR	3	n/a		There is a relative autonomy of cities, counties and schools for the primary and secondary education
	DE	3	78%	0 hour	The duty for education is at the Länder level that has a very wide autonomy.
	LT	3	n/a	0 hour	The choice of content, timing, textbooks and other material are given to teachers but they have some possibility to change the general curriculum up to 10%
	RO	3	n/a	116 hours	the possibility exists for teachers to develop courses based on the main curriculum on the school decision principle, a good strategy to include new topics in the programme
Group 3 Countries or regions with **less flexible** curriculum & provision of education	GR	2	10%	0 hour	In Greece, the curriculum for all secondary education schools are formulated at national level by the Ministry of Education, and all schools use the same set of course books and supplementary material
	TR	2	55%	48 hours	Teachers do not have flexibility to regulate the contents of the school programmes and the special needs and circumstances of the class into account.

Table 14: Mapping exercise for the NANOPINION PROJECT - final clusters

* Asturias and Catalonia

4.1.6 Strategies:

Now that we have clustered the countries in three groups in function of the flexibility of their educational system in various dimensions, we will propose corresponding strategies. These strategies also rely on the analysis of the possible connections with existing subjects in various curricula presented in point 4.2.

We will not propose fundamentally different strategies based on this distinction, but suggest some adaptation to the relative rigidity of national and regional curricula. The common point for all the analysed curricula is the inadequate or inexistent provision of resources to provide education on the NST topics. This means that some elements of strategy to integrate NST in the programme will be common for all curricula.

As exposed in the paper produced by Virginie Albe for the ESERA 2012 conference, teachers' professional development on NST have highlighted two strategies to integrate NST in the curriculum. The first one proposes the integration of NST related topics into the whole science curriculum while the second one consists in creating a specific nanoscience module into the curriculum. "*Teachers tend to favour specific designed teaching activities to integrate nanoscience and nanotechnologies in class. This result may converge with the previously identified teaching strategy of teachers privileging an extension of the science curriculum on nanoscience and nanotechnology*." [49]

The countries participating in NANOPINION most likely to adopt the strategy consisting in creating an independent module on NST are the **countries with most flexible educational systems and curriculum definition**. The countries from the first cluster (Denmark, Finland, Italy, Israel and Spain) may be relevant to test the integration of a module dedicated to NST.

This strategy could also be adopted in countries that have specific subjects in their curriculum on current science research and application in technology like Spain and Greece.

Countries from the second cluster (Bulgaria, Czech Republic, Germany, Croatia, Lithuania and Romania) that are **flexible** but in a smaller proportion than the first group should be used to validate another strategy consisting in integrating hours to teach NST related topics only as illustrations linked to other existing topics

The curricula that are less flexible for integration of new topics (cluster 1 and 2) require tools and resources that are very easily adapted to the needs of teachers and require short duration of time to be included in the class activities. On the other hand, very flexible curriculum will allow teachers to implement longer term NST modules given at a full school year for example.

A strategy to integrate more NST in somehow less flexible curricula could be to foster a bottom-up approach, designing short exercises related to different topics of the curriculum. Each demonstration or exercise should not take more than 10 to 25 minutes. This way NST could be integrated in classes without asking permission from state authority and without instant need to change national curriculum.

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[49] Albe, Virginie (2013).

4.2 NST topics and curriculum subjects

The curriculum review carried out in the previous section based on Teacher Coordinators survey answers and desk research shows that only three countries (HR, IL and ES) have NST included as a sub-topic. In all the 13 school systems subject of this present mapping, schools have inadequate or inexistent resources to provide education on the NST topics. Figure 5, representing the answer given by NANOPINION Teachers' Coordinators on the place of Nanotechnology in their school programme shows that in most countries (66,7%), it is not a mandatory subject, chapter or topic in the curriculum. In 27,8% of the countries represented in the NANOPINION project, Nanotechnology is not a chapter in itself in one of the scientific subjects but addressed as a topic in other chapters. Only one country has Nanotechnology has core chapter in one of the scientific subjects of the curriculum.

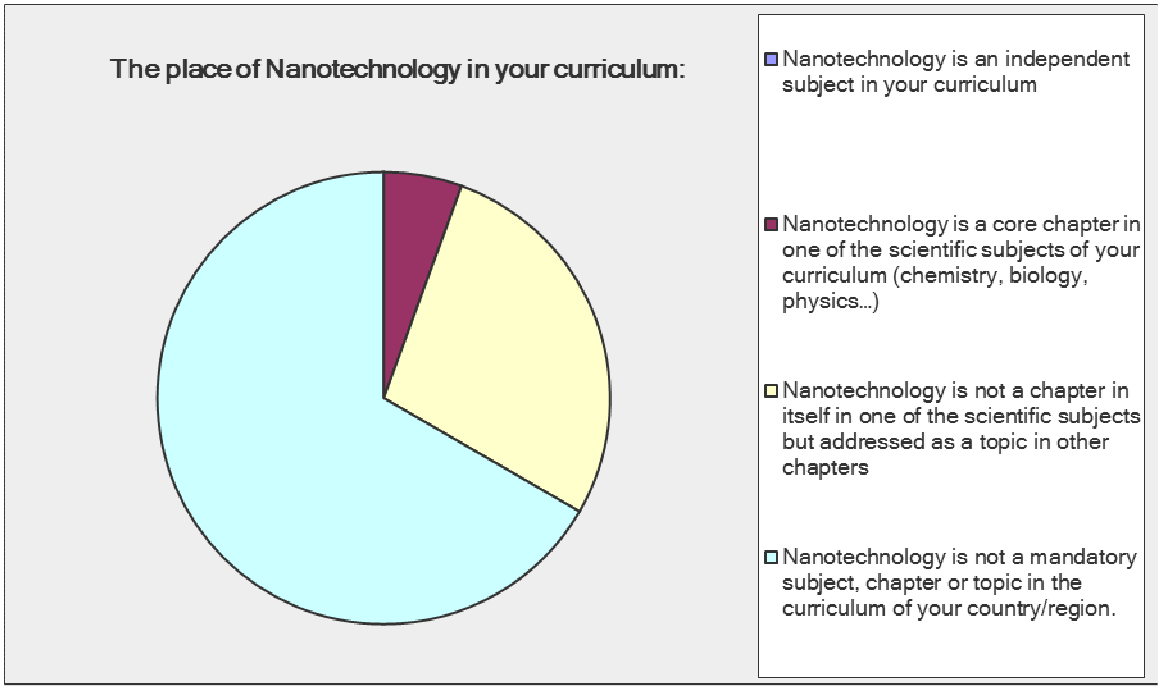

Figure 5 – Answer to question asked to NANOPINION Teachers' Coordinators: "*Please tick the relevant answer regarding the place of Nanotechnology in your curriculum*"

In addition, the results of the survey answered by the Teachers' Coordinators shows (see figure 6) that most of the applications of Nanotechnology that will be used in the educational resources developed for the project are not covered as main chapter but appear as subtopic in science courses.

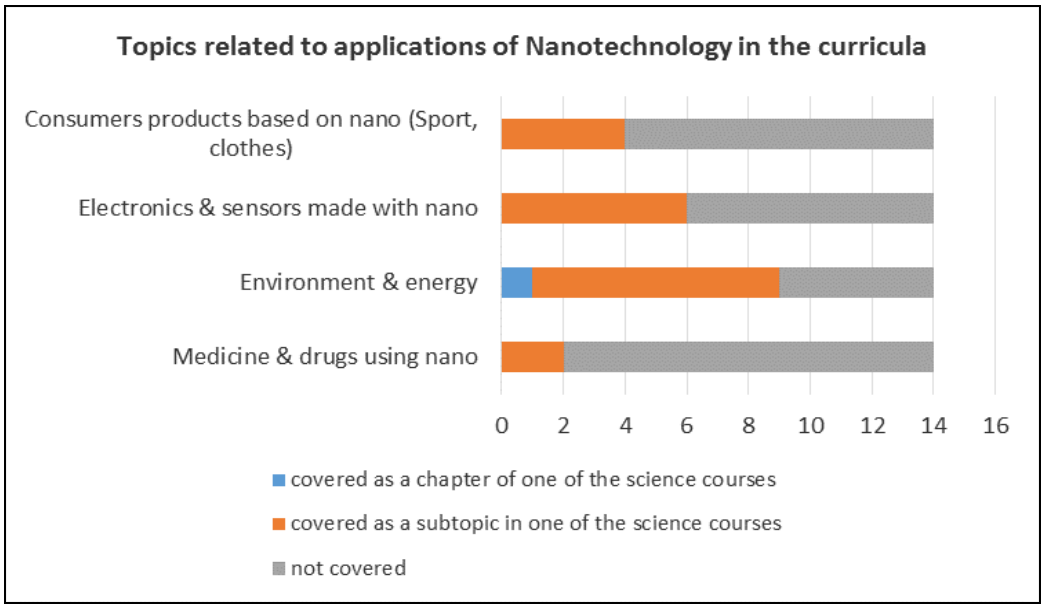

Figure 6 – Answer to question asked to NANOPINION Teachers' Coordinators: "*Please specify if the topics related to applications of Nanotechnology listed are covered in any way in the curriculum of your country/region*"
Horizontal axis: Number of positive answers given by Teacher Coordinators; Vertical axis: applications of Nanotechnology

In this regard, the Romanian Teacher Coordinator specifies that "*NST is not a chapter in the science curriculum (Chemistry, Biology or Physics) in Romania. As NST is a very new science, the majority of science teachers do not have basic knowledge about the subject to be able to teach it. The Romanian Ministry of Education, Research, Youth and Sports nor teacher training centres for professional development organises courses in this field.*"

In addition, the study carried out by Antti Laherto highlights that teachers (in Finland in this case) feeling regarding this new topic is generally sceptical due to poor resources or no resources available to provide NST education and strongly emphasise the need to organise in-service training to provide the necessary basic knowledge and competences to the teachers.[50]

However, all NANOPINION Teacher Coordinators involved in this mapping have presented correlations and possibilities to integrated NST in the different subjects of their curriculum. The links with the various subjects of the curricula are made with NST in general and with four applications of Nanotechnology in particular:

- medicine and drugs
- environment and energy
- electronics and sensors
- consumers' products

[50] Laherto, Antti (2011) *Idem*

4.2.1 Application on NST in Medicine and Drugs curricula

As shown in Table 15 below, Teacher Coordinators' suggestions to integrate applications of Nanotechnology in medicine and drugs in the curriculum focus on Chemistry and Biology as adequate subjects.

Applications on NST in medicine and drugs in the Chemistry curriculum can be developed within several topics: *organic Chemistry*, *chemical kinetics*, *and chemical synthesis* (Bulgaria and Turkey). The Finish Teacher Coordinator suggests integrating it in a Chemistry topic called *organic nature and the society,* which has a more general character.

Six Teacher Coordinators mention **Biology** as a subject where applications on NST in medicine and drugs are well fitted. *Cell functions*; *human anatomy, genetics and applied biotechnology, including bioinformatics are* mentioned as possible chapters (BG, DK, DE, IT, IL and TK).

Physics is not mentioned by any Teacher Coordinator as a subject that is compatible with topics on NST in medicine and drugs.

Some countries suggested **other science related subjects** for the topic. Greece - with the subject called *scientific research* - and Spain with the subject *Sciences for the contemporary world* have possibilities to integrate NST related lessons. In that case, the material should give students a basic understanding of the scientific methods and principles.

Finally the Teacher Coordinators from Lithuania, Romania and Croatia have not suggested any specific way to integrate this topic in the curricula.

Topic and Countries	Chemistry	Biology	Humanities/other
Medicine and drugs	*Diagnostic medicine*	*Diagnostic medicine/ Examples of nano-dugs/ Bone graft substitute*	
Bulgaria	Grade 9 – (age 13-14) Topic: *organic Chemistry* Grade 10 (age 14-15) topic: *Chemical kinetics and technology*	Grade 9 (age 13-14) Topic: *Chemistry of the cells*	
Croatia	n/a	n/a	n/a
Czech Rep.	n/a	Could be integrated	n/a
Denmark	n/a	Various subjects in 8th and 9th grade. Topic example: *genes as carriers of biological information and their importance to heredity* or at gymnasium level under the topic: *Understanding of applied biotechnology, bioinformatics* and *investigative and analytical methods and statistical processing of results in the fields of physiology, genetics, evolution, biochemistry, immunology and ecology.*	
Finland	Under the chapter: *Organic nature and the society*. There is already one subtopic under that chapter about *detergents, cosmetics and textiles.*		
Germany	Could be integrated	Could be integrated	
Greece	n/a	Cell function and drug design	New course called The basic principles of scientific research in grades 10 and 11 (ages 15-17). Duration 2 hours/week for a total of 52 weeks.
Israel	n/a	Chapter of *genetic engineering, genetic cure, diseases diagnostic* and. *Human anatomy, physiology*, and *micro-organisms*. 2-3 hours per month. Could also be linked to subject like *Genetic treatments and Engineering*. Presenting new targeted medicines to cancer treatment.	n/a
Italy		In the chapters of *cells* and *the human body* in the curriculum in the first years of all types of secondary schools.	n/a
Lithuania	n/a	n/a	n/a
Romania	n/a	n/a	n/a
Spain	n/a	n/a	The subject *Sciences for the contemporary world* is flexible and holds various possibilities for integrating NST related lessons.
Turkey	During the 2nd year of secondary education (age 15-16) in chapter on chemical synthesis.	n/a	n/a

Table 15: Possible integration of NST Medicine and drugs in Curricula

4.2.2 Application on NST in Environment and energy curricula

Table 16 provides an overview on how Teacher Coordinators would integrate applications of NST in environment and energy in their national curriculum. In comparison to medicine and drug topics, environment and energy are more popular topic which is treated in most national curricula. The topic is integrated in various ways in subjects like Physics, Chemistry, Biology, and other topics like earth science are mentioned.

Teachers that mention the **Physics curricula** as a possibility to treat NST in environment and energy suggests chapters like mechanic energy, energy conservation and electronics are taken into play (BG, CZ, DK, FI, DE, IT, LT and TK).

Teachers mentioning the **Chemistry** curricula for the NST in environment and energy topic are not specific in their suggestions (BG, DE, DK, GR, IL, IT and LT). Only Turkey brings up a specific chapter on thermo Chemistry as a possible option to integrate knowledge on NST in environment and energy in the class room.

Biology is also suggested by some countries without further specifications on how (DE, DK, IL and IT). Only the Croatian Teacher Coordinator gives a concrete suggest on how to fit the topic into two specific chapters of the curricula: nature and men and sustainable development.

Many countries can integrate NST in environment and energy topic in **other** ways. As mention in the previous section the subject from the Greek curriculum called *scientific research* and the Spanish subject *Sciences for the contemporary world* holds the possibility as long as the scientific methodology and principles are emphasised in the applications. Italy would be able to integrate the topic in the science subject called Earth science. Finally the German and Israeli Teacher Coordinator find the topic suitable for humanistic subjects, which would generally mean the approach would have to be ELSA oriented.

Topic and Countries	Physics	Chemistry	Biology	Humanities/other
Environment and energy applications	***Elastic electronics/ Surface volume***	***Dyes and electron donors/ Photocatalytic***	***Biomimetic - chlorophyll***	
Bulgaria	Grade7-10 Topic: *Energy*	Grade 7 and 10 - Topic: *Energy and Chemistry*	n/a	n/a
Croatia	n/a	n/a	Students aged 17-18, chapter: *Nature and Men*, under subchapter: *sustainable development*. Focus: fusion, new fuels and NST. 2 hours per year.	n/a
Czech Republic	2 hours per week in all years of study and in the schools *Technical lyceum* - 3 hours per week in all years of study.	n/a	n/a	n/a
Denmark	In the 9th grade, in the topic: *society's resources and energy*. In the 8th grade, in the topic*: energy transfer, including electric power transmission* (Chemistry and Physics is one subject)	In the 9th grade, in the topic *Evaluate products according to their production processes load on the environment* (Chemistry and Physics is one subject)	Various subjects in 8th and 9th grade: *natural and anthropogenic changes in ecosystems and their importance for the biological diversity*. At gymnasium under the topics: ecosystem and ecotoxicology.	n/a
Finland	In mechanics chapters: *mechanic energy* and in heat chapter: *conservation of energy, heat and electricity.*	n/a	n/a	n/a
Germany	Environmental topics including renewable energies are fixed in nearly all subjects in the secondary school. 8 and 10 (14 and 16 years old students).	idem	idem	idem
Greece	Could be integrated	Could be integrated	n/a	New course "The basic principles of scientific research" in grades 10 and 11 (ages 15-17). 2 hours/week 52 weeks.
Israel	Wide range of environmental projects within the curriculum starting from low grades.	idem	idem	idem
Italy	Can be approached in various subjects in the first years of all types of schools. It can then be delved deeper in 5th year courses possibly working together with Chemistry	idem	idem	idem
Lithuania	This is a subtopic of Physics science (grade 11-12) on electronics.	It's possible also during Chemistry lessons (grade 11-12).	n/a	n/a
Spain	n/a	n/a	n/a	Subject Sciences for the contemporary world is flexible and holds various possibilities for integrating NST.
Turkey	Environment and energy can be combined with electronics and sensors made with nano, For example in the curriculum of the 3rd year of the secondary education year.	During the 3 year of the secondary education (students aged 16-17) one Chemistry chapter focuses on *thermo Chemistry*. 1 lesson of 40 minutes.	n/a	n/a

Table 16: Possible integration of NST Environment and energy applications in Curricula

4.2.3 Application on NST in Electronics and sensors

The Teacher Coordinators' suggestions on how to implement applications on NST in Electronics and sensors in the national curriculum are not as well covered as in the previous topics on medicine and drug and environment and energy.

Teachers that mention the **Physics curricula** as a possibility suggests chapters like electrostatics, electromagnetic and electric current and the structures and the dimensions of nature and electricity (BG, DK, FI and GR).

Italy mentions that the **Physics and Chemistry** subjects can integrate the topic, but without specifying how. However as the Italian current school reform is not very much integrated it would seem approachable to integrate the NST in electronics and sensors in physic classes regardless of the applications developed on the subject.

The Teacher Coordinator from Finland mentions the **Chemistry curriculum** as a possibility to treat NST in electronics and sensors within the topics named explaining the structure and quality of the elements and compounds.

The Czech Republic is the only country that suggests integrating the topic in what is called **Chemistry and Biology** classes, which is a combined subject that holds a chapter on atomic Physics – which again is a topic that normally belong to the field of Physics.

Three countries mention that it is possible to integrate the NST in electronics and sensors topic in **other** ways. Greek on the basis of the subject scientific research and Spain on the basis of the subject Sciences for the contemporary world as long as this topic also takes considerations on scientific methods. The German teacher coordinator suggest integrating the topic in a more untraditional way, namely in computer Science courses under the chapter reduction of the size of processors.

Topic and Countries	Physics	Chemistry	Biology	Humanities/ other
Electronics and sensors	***Hierarchal structure result in strength***	***Hydrophobic materials***	***Biomimetic snails shells– lotus effects***	
Bulgaria	Grade 7 and 10 Topic: *Electrostatics, electromagnetism and electric current.*	n/a	n/a	n/a
Croatia	Students aged 17-18, chapter: *Materials and materials properties* under the sub-chapter: *Atoms, nucleus and elementary particles.* 2 hours per school year.	n/a	n/a	n/a
Czech Republic	No suggestion	Could be taught under the topic: *atomic Physics* representing 10 hours in the curriculum of the fourth year of study in Chemistry and Biology subjects.	n/a	n/a
Denmark	In 9th grade, in the topic: *everyday life technology and its impact on the individual and society* (Chemistry and Physics is one subject) At gymnasium level in the subject: *Natural Science foundation course*	n/a	n/a	n/a
Finland	In the chapter called *The structures and the dimensions of the nature* and *electricity*.	In the chapter "*Explaining the structures and quality of the elements and compounds.* "	n/a	n/a
Germany	n/a	n/a	n/a	Could be approached during Computer Science course in form 9 or 10 (15-16 years old students) when the reduction of the size of processors is tackled.
Greece	Could integrate lessons on the order of *magnitude in Nanotechnology, Nanoscale, measurement techniques and instruments* and secondly about Radiation-*matter interactions, dominant forces in nanoworld, vs. dominant forces in everyday life* (rel. to Physics courses).	n/a	n/a	New course called *The basic principles of scientific research* in grades 10 and 11 (ages 15-17). Duration 2 hours/week for a total of 52 weeks.
Israel	n/a	n/a	n/a	n/a
Italy	Can be integrated in 5th year level.	Can be integrated in 5th year level.	n/a	n/a
Lithuania	n/a	n/a	n/a	n/a
Romania	n/a	n/a	n/a	n/a
Spain	n/a	n/a	n/a	The subject Sciences for the contemporary world is flexible and holds various possibilities for integrating NST related lessons.
Turkey	n/a	n/a	n/a	n/a

Table 17: Possible integration of NST Electronics and sensors applications in Curricula

4.2.4 Application on NST in Consumers' products

The topic on NST in consumers' products is possible to cover in very diverse ways. The teacher coordinators suggest both Physics, Chemistry, Biology and other topics to cover this field, where as **Biology** is only suggested by three countries without specification (BG, DE and IT). The German coordinate only mentions the "lotus effect illustration" is a way to talk about the NST in consumers' products topic for students aged 12-13.

The Finish Teacher Coordinator is the only teacher to suggest a specific chapter in the **Physics** curriculum that is capable of integrating the topic on NST in consumers' products. The specific suggestion is mechanics. Bulgaria, Czech Republic and Italy suggest the Physics subject without further specifications.

Six Teacher Coordinators mention that Chemistry is an appropriate subject to teach NST in consumers' products. Topics of the curricula that are suggested for this purpose are: *textile, chemical reactions chemical bonds and matters and its properties chemical synthesis and reactions rates and our lives* (DK, FI, EL and TK). Both Bulgaria and Italy mentions Chemistry as a possibility without specifications.

Germany, Greece, Italy and Spain could integrate the NST in consumers' products topic in **other** subjects. Also here the general Greek the Spanish sciences subject are compatible with the topic as long as it also related the understanding on scientific methods. The German and Italian Teacher Coordinator do not suggest a subject for the topic.

Topic and Countries	Physics	Chemistry	Biology	Humanities/other
Consumers products based on nano	***OLEDS/ Sensing events***	***Forces between molecules***	***Antigens***	
Bulgaria	Grade 5 - 12	Grade 5 - 12	Grade 5 - 12	n/a
Croatia	n/a	n/a	n/a	n/a
Czech Republic	Could be integrated	n/a	n/a	n/a
Denmark	n/a	In 9th grade, in the topic *Evaluate products according to their production processes load on the environment* (Chemistry and Physics is one subject). At gymnasium level under the topics: *substances structure and chemical and physical properties*	n/a	n/a
Finland	Sports products introduced in the mechanics chapter.	Could be done in the subtopic *textiles*, where nano-clothes could be taken as an illustration.	n/a	n/a
Germany	n/a	n/a	n/a	In form 6 and/or 7 (12-13 years old students), for example using the lotus-effect as illustration,.
Greece	n/a	Chemical reactions and formation of chemical bonds (rel. to Chemistry courses).	n/a	New course called *The basic principles of scientific research* in grades 10 and 11 (ages 15-17). 2 hours/week for a total of 52 weeks.
Israel	n/a	n/a	n/a	n/a
Italy	Could be approached at all science subjects in all schools early years.	Idem	Idem	Idem
Lithuania	n/a	n/a	n/a	n/a
Romania	n/a	n/a	n/a	n/a
Spain	n/a	n/a	n/a	Sciences for the contemporary world
Turkey	n/a	In the 1st year of secondary school, (students aged 14-15) in chapter on *matter and its properties* and the *changes in the properties of matter at nano scale*. Introduction of magnetic property of nano-materials, elements and different surface areas of nano-materials. (3 lessons of 40 minutes in a school year). In 2nd year (students aged 15-16) in chapter on *chemical synthesis and reaction rate*. 2 lessons of 40 minutes of a school year. In the chapter called *Our lives*. 2 lessons of 40 minutes	n/a	n/a

Table 18: Possible integration of NST Consumers products applications in Curricula

4.2.5 Application on NST in ELSA

The topic on NST and ELSA is also mentioned by some teachers as a strategy to integrate more NST topics in general. As show in Table 18, Italy suggests both philosophy and law. Some countries suggested **other subjects** that are still science related. Greece and Spain have with their general science subjects a vast possibility to also discuss ELSA issues.

The German Teacher Coordinator suggests English and German subjects as a way to introduce ELSA discussions with the students.

Topic and Countries	Humanities/other
ELSA	
Croatia	Additional possibility
Germany	Some lessons from English and German can be used to introduce ELSA-aspects.
Greece	New course called *The basic principles of scientific research* in grades 10 and 11 (ages 15-17). Duration 2 hours/week for a total of 52 weeks.
Italy	philosophy and law
Spain	The subject Sciences for the contemporary world is flexible and holds various possibilities for integrating NST related lessons.

Table 19: Possible integration of NST ELSA applications in Curricula

The lack of resources on NST in European schools system should be filled preparing the teachers at the occasion of in-service training to improve their capabilities.

4.3 Subject recommendations and curriculum flexibility

This section examines the possible tendencies in the Teacher Coordinators' subject recommendations when viewing how to integrate the suggested applications of nanotechnology (medicine & drugs, environment & energy, electronics & sensors and consumers products). The *subject popularity*[51] is measured in the three country groups categorised in section 4.1 (most flexible, flexible and less flexible), with the purpose of finding possible strategic approaches for integrating the suggested nanotechnology applications in the country groups.

Section 4.1 gave an overview of the curriculum flexibility of the 13 countries described in this report. The countries are grouped into 3 different categories on the basis of different variables (the possibility teachers or schools have to integrate new topic, allocated teaching time, place given to the flexible timetable of the curriculum, regulatory level). Section 4.2 examined how 4 suggested applications of nanotechnology

[51] Expression for indicating the level of teacher coordinators' recommendation of a subject for a integrating a nano-application in the curriculum.

(medicine & drugs, environment & energy, electronics & sensors and consumers products and ELSA applications when mentioned) can possibly be integrated in different schools subjects (Physics, Chemistry, Biology or other subjects). This chapter meanwhile tries to find correlations between curriculum flexibility and subject popularities for the suggested applications of nanotechnology.

As the amount of countries in each group varies the identification of possible correlations is based on an index review which makes it feasible to compare tendencies within each of the three country groups. The three figures below present an overview of the subject popularity to integrate NST in each of the groups.

The figures are based on a coordinate system where coordinate axis X represents the school subjects suggested by the teachers (Physics, Chemistry, Biology or other subjects) that can be used to integrate the applications of nanotechnology.

The coordinate axis Y represents the index popularity of each of the suggested applications of Nanotechnology. The popularity index means the frequency each application of Nanotechnology was suggested for a school subject.

For example if one of the less flexible curricula has mentioned Chemistry as a subject where it is possible to integrate applications on nano medicine & drugs the popularity index would be:

$$\frac{1 \text{ (amount of countries that suggested Chemistry to integrate nano medicine \& drugs)}}{2 \text{ (total amount of countries in the less flexible group)}} = 0{,}5 \text{ (popularity index)}$$

For further details, the index tables can be found in annex 2.
Figure 7 gives an overview of the subject popularity for each of the five mentioned nano-applications in countries with most flexible curricula (DK, FI, IL, IT and ES).

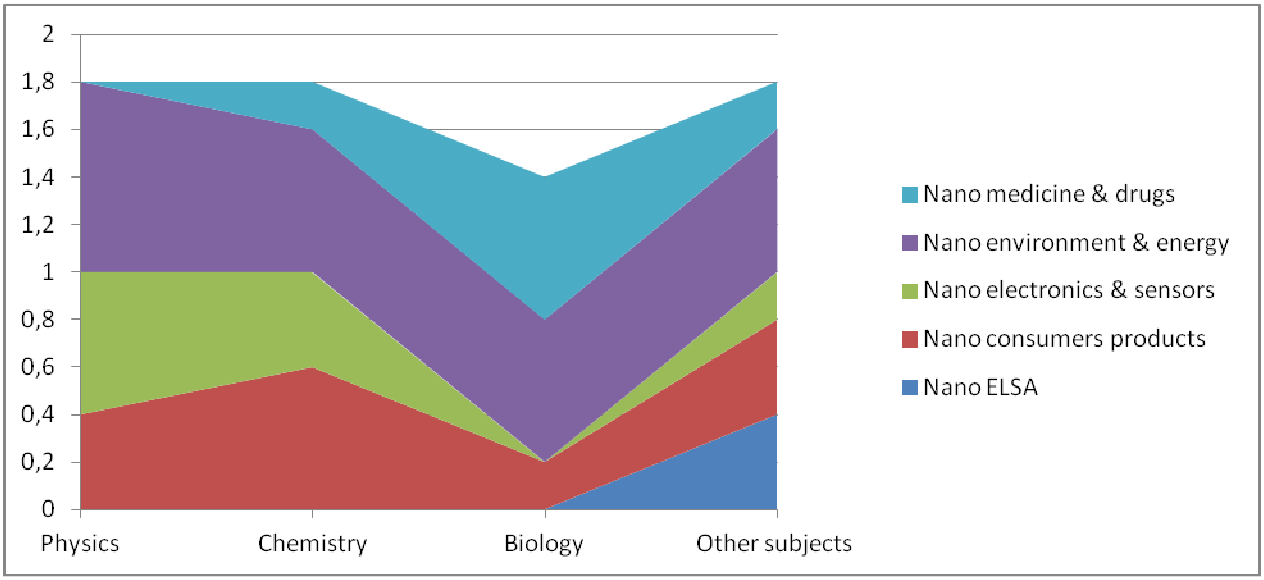

Figure 7: Subject popularity in countries with flexible curriculums

Figure 7 clearly shows that Biology is the less recommended subject (especially because it is not suggested for the, electronics & sensors application and is less popular for consumer products) in countries with flexible curricula. Both Physics and Chemistry have an equal level of popularity, with the exception that the teachers do not find Physics compatible with nano applications for medicine and drugs, while nano applications on environment and energy is recommended as a good subject for Physics. The figure also shows that in countries with flexible curricula it is feasible to integrate nano-applications in other subjects (including humanities) which gives space for ELSA topics.

Figure 8 gives an overview of the subject popularity in countries with flexible curricula (BG, CZ, DE, HR, LT and RO) for each of the five nano-applications mentioned above.

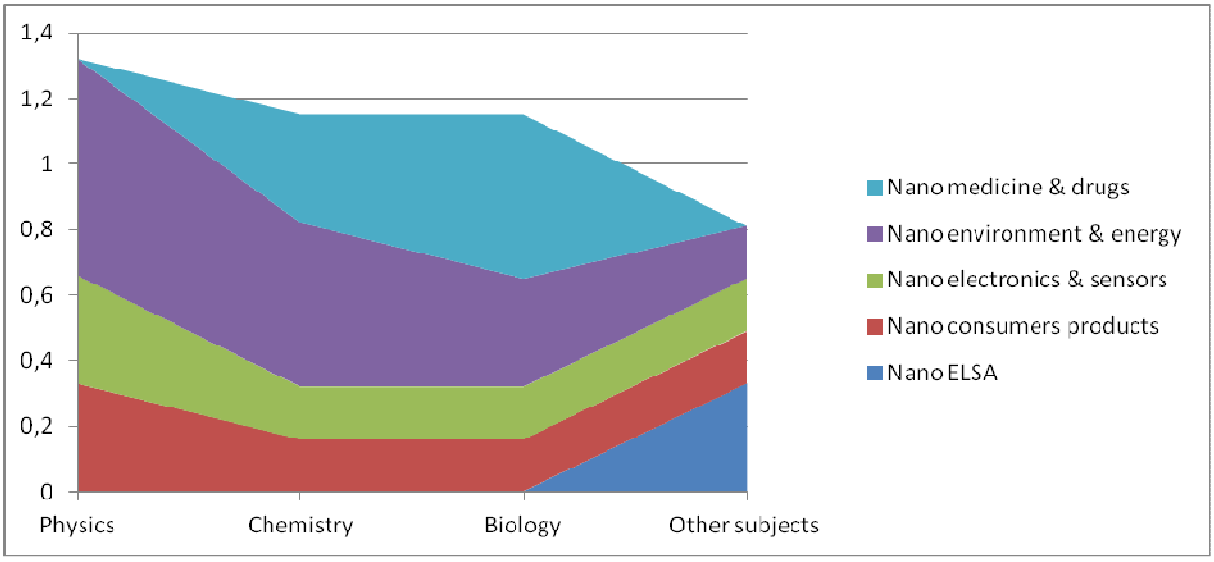

Figure 8: Subject popularity in countries with semi flexible curriculums

In countries with flexible curricula other *subjects* is a less frequently suggested category by the Teacher Coordinators. Instead Physics is the most popular subject, even though it was not suggested for nano-applications in medicine and drugs. The figure in general makes it evident that a strategy for integrating nano applications in countries with semi flexible curricula should be based on applications that can be integrated in the traditional science subjects (Physics, Chemistry and Biology).

The data from the countries with less flexible curricula (EL and TK) are represented in figure 9.

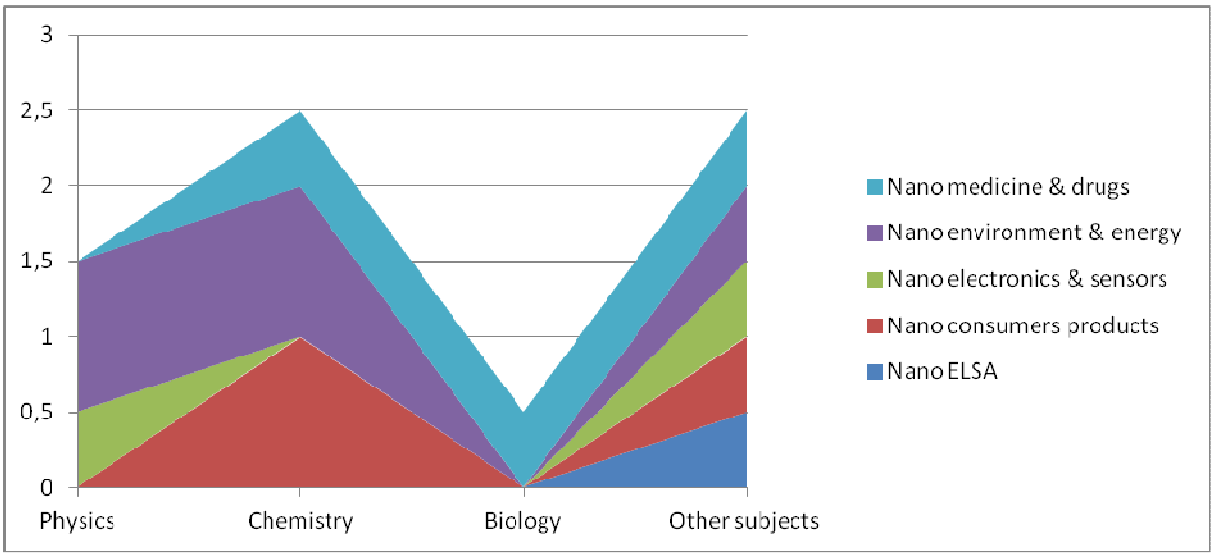

Figure 9: Subject popularity in countries with less flexible curriculum

Figure 9 shows that Chemistry and other subjects are the most frequently suggested subject by Teacher Coordinators from less flexible curricula. Biology is only suggested as a passable subject for integrating nano-applications on medicine and drugs. While Physics and Chemistry is well suited for integrating nano-applications on environment and energy. Chemistry is suggested as a feasible way to integrate nano-applications in consumer products.

It is evident that the analysis of the subject popularity in each of the three country groups should be taken with some reservations. Especially the group of countries with less flexible curricula is only constituted by 2 countries, the consequence is that the index values are 0, 0,5 or 1 for which figure 9 shows more emphasised tendencies in comparison to the other group figures that is based on preferences from 5-7 countries (see annex 2 with index tables).

Also it is worth mentioning that there is no evident causal relation between curriculum flexibility and subject preferences for integrating nano-applications. Therefore the tendencies indicated in this section should only be used as possible approaches to find coincidental correlations which can help ease the development of teaching resources on NST for the 13 countries treated in this report that in many ways have very different science curricula and education systems.

5. Conclusion

The mapping exercise undertaken to create clusters of European school curricula (national and regional) had the objective to suggest how to best incorporate Nanoscale science and technology (NST) in the participating countries of the NANOPINION project.

This mapping analysed how the NST applications used in NANOPINION to develop resources can be linked to the various parts of the specific curricula of the 13 curricula involved in the project.

The mapping exercise suggested some clusters of European countries to tailor how to use the NANOPINION platform for each country – according to the flexibility of the school programmes and the level and space NST can take in the curricula.

The methodology used was to collect information from science teachers from each of the 13 countries and regions acting as national/regional coordinator in the project and on desk research carried out by EUN. The information gathered from the Teachers Coordinators was collected through a survey designed to understand how their curriculum is structured and how NST can be integrated and linked to the various subjects. Combining information gathered from teachers and desk research enabled to include the perspective of the actors that are key for the evolution of the teaching practices and know the practical reality of the classroom together with theory and figures from studies.

The report provides 13 country profiles including a brief introduction on the school system and curriculum at secondary level followed by information on the possibility to include NST in general and some NST applications in particular.

The following part of the report proposes clusters of countries according to the flexibility of their schools systems and curricula. For each of them, additional analysis was made to look into this specific characteristic. Three groups of countries are proposed based on the flexibility of their school system and curricula: the most flexible (DK, FI, IL, IT and ES), the somehow flexible (BG, CZ, DE, HR, LT and RO) and the less flexible (GR and TK).

The report then reviews the various entry points in the existing subjects of the 13 curricula providing additional elements of information to develop NANOPINION resources and strategies to integrate NST in each of the school curriculum for students aged 12 to 18.

For all three country groups NST applications in **medicine and drugs** are best integrated if linked to the Chemistry (organic, chemical genetics and synthesis) and Biology (cells, human anatomy and genetics) subjects highlighting scientific methods. Lithuania, Romania and Croatia do not have suggestions on how to integrate this topic but are all semi-flexible countries and therefore have margin to integrate new topics and examples.

The applications of NST related to **environment and energy** are approach in all countries with quite a lot of variations. Most of the proposition (8 in total) are to link it to the Physics subject. The suggestions are mainly to link it to mechanics engineering, energy conservation and electronics. Seven Teacher Coordinators propose to link these applications of Nanotechnology with the Chemistry subject but they do not give specific suggestions. Only Turkey proposes to approach it in thermo-chemistry. Link with Biology is also very general and more related to sustainability.

Additional possibility proposed by Italy is to approach that in the subject called "Earth Science". Germany and Israel mention the possibility to approach these applications from the ESLA perspective in humanities subjects.

Teachers Coordinators from countries with most flexible curricula have a tendency to find nano applications on environment and energy compatible with Physics. Teachers Coordinators from countries with less flexible curricula find both Physics and Chemistry well suited for integrating nano-applications on environment and energy.

Electronics sensors based on Nanotechnology is a topic that was more difficult to relate to existing curriculum subjects. Only three Teacher Coordinators made concrete suggestions. The most evident subjects was Physics, more specifically electrostatic, electromagnetic, structure and dimension of nature and electricity. Two Teacher Coordinators suggested linking this application to Chemistry. Even though Biology is mentioned, it refers to sub-topics that are more related to Physics like atomic Physics or structure and quality of the elements and compounds. The German Teacher Coordinator suggests to approach this application of Nanotechnology in different way with Computer Sciences talking about reduction of the size of processors.

The **consumers' products** developed with Nanotechnology are not clearly linked to certain subjects of the curricula. Only five Teacher Coordinators on thirteen are suggesting links. In Physics, the only suggestion is to relate it to the mechanic chapter. There are much more suggestions to relate this application with the Chemistry subject (chemical reactions and bonds). The German Teacher Coordinator mentions the water-proof textile based on the lotus effect (Biology). Approaching the **ELSA** issues related to NST can be an interesting way to integrate the topic in the curriculum. The Italian Teacher Coordinator suggests philosophy and law and the German Teacher Coordinator suggest linking ELSA to languages subjects. While looking at the possible tendencies in the country groups on subject recommendations it is possible to say with some reservation that countries with most flexible curricula finds it feasible to integrate nano-applications in other subjects (including humanities) which gives more space for ELSA oriented applications. In countries with flexible curricula *other subjects* is a less frequently suggested category while traditional science subjects (Physics, Chemistry and Biology) are suggested more frequently for integrating nano applications. Finally Teacher Coordinators from countries with less flexible curricula have little preferences for Biology even though it is a passable subject for integrating nano-applications on medicine and drugs. Here Physics and Chemistry areas recommended for integrating nano-applications on environment & energy consumer products.

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Annex 1 - NANOPINION survey

Mapping Nanotechnology in European curricula

1. Name and Surname: **Open question**

2. Country: **Drop Down (Bulgaria, Spain, Greece, Italy, Germany, Croatia, Finland, Czech Republic, Israel, Lithuania, Turkey, Romania)**

3. Region: **Open question**

4. City/Town: **Open question**

5. What is the geographical scope of the curriculum you are following, at which authority level is it formulated (National, Regional…)?

Please explain the local/national context of the curriculum you are following in the box below in approx. 100 words.

Open question

6. Please tick the relevant answer regarding the place of Nanotechnology in your curriculum:
   Multiple choices
   - Nanotechnology is an independent subject in your curriculum
   - Nanotechnology is a core chapter in one of the scientific subjects of your curriculum (Chemistry, Biology, Physics…)
   - Nanotechnology is not a chapter in itself in one of the scientific subjects but addressed as a topic in other chapters
   - Nanotechnology is not a mandatory subject, chapter or topic in the curriculum of your country/region.

7. Please explain how Nanotechnology is integrated in your curriculum or if it is not officially part of the curriculum, how it could be best integrated specifying the following:
   - Subjects to relate with (Biology, Physics, Chemistry...)
   - The attainment target level, learning goals for students
   - The types of activities
   - The number of hours dedicated to it per week and in total on a school year

   Please provide a text of approx. 200 words.
   Open question

8. Are you aware of any plan to integrate Nanotechnology in the curriculum of your country/region in the near future? Please explain
   Open question

9. Please specify if the topics related to applications of Nanotechnology listed below are covered in any way in the curriculum of your country/region
   Multiple choices - Matrix

Applications	**In which way is it covered?**
• Medicine & drugs using nano • Environment & energy • Electronics & sensors made with nano • Consumers products based on nano (fabrics, Sport gear, coating)	• covered as a chapter of one of the science courses; • covered as a subtopic in one of the science courses; • not covered.

10. Please explain the best way to connect the applications of Nanotechnology mentioned above to the curriculum of your country/region
    Please provide a text of approx. 150 words.
    Open question

11. Please add any comment on the place of Nanotechnology concepts and topics in the curriculum of your country/region if not covered by the previous questions.
    Open question

Annex 2 - Subject recommendations and curriculum flexibility – Index tables

	Physics	Chemistry	Biology	Other subjects	Total
Nano ELSA	0	0	0	0,4	0,4
Nano consumers products	0,4	0,6	0,2	0,4	1,6
Nano electronics & sensors	0,6	0,4	0	0,2	1,2
Nano environment & energy	0,8	0,6	0,6	0,6	2,6
Nano medicine & drugs	0	0,2	0,6	0,2	1
Popularity	1,8	1,8	1,4	1,8	

Table 20: Index table of subject popularity in most flexible countries (DK, FI, IL, IT and ES)

	Physics	Chemistry	Biology	Other subjects	Total
Nano ELSA	0	0	0	0,33	0,33
Nano consumers products	0,33	0,16	0,16	0,16	0,81
Nano electronics & sensors	0,33	0,16	0,16	0,16	0,81
Nano environment & energy	0,66	0,5	0,33	0,16	1,65
Nano medicine & drugs	0	0,33	0,5	0	0,83
Popularity	1,32	1,15	1,15	0,81	

Table 21: Index table of subject popularity in flexible countries (BG, CZ, DE, HR, LT and RO)

	Physics	Chemistry	Biology	Other subjects	Total
Nano ELSA	0	0	0	0,5	0,5
Nano consumers products	0	1	0	0,5	1,5
Nano electronics & sensors	0,5	0	0	0,5	1
Nano environment & energy	1	1	0	0,5	2,5
Nano medicine & drugs	0	0,5	0,5	0,5	1,5
Popularity	1,5	2,5	0,5	2,5	

Table 22: Index table of subject popularity in less flexible countries (GR and TK):