Lifelong Learning Programme

Lifelong Learning Programme
Information and communication technologies - ICT (KA 3)

Nano Tech Science Education
Grant Agreement No 2010-4223/001-001

EVALUATION REPORT OF 2ND QUESTIONNAIRE

METHODS AND RESULTS OF THE NTSE VIRTUAL LAB IMPLEMENTATIONS – TURKEY

FIRST AND SECOND TEST IMPLEMENTATION PROCESS: STUDENTS' QUESTIONNAIRES

The charts are drawn based on the first implementation period of the lesson plans developed within the project. The results are based on the students questionnaires conducted after the lessons. The questionnaires were conducted in two phases according to the implementation stages, completion of virtual laboratories and redesign of the lesson plans with inquiry-based learning. The first implementation stage, including 5 experiments, continued till March 2013. The data shown in the charts reflect ideas and thoughts of 195 students with an age range of 13-17 from 15 different schools[1] of elementary and high school level related to the components of virtual laboratory and our educational materials (guidelines, simulations, videos etc.) in the 1st Implementation Phase.

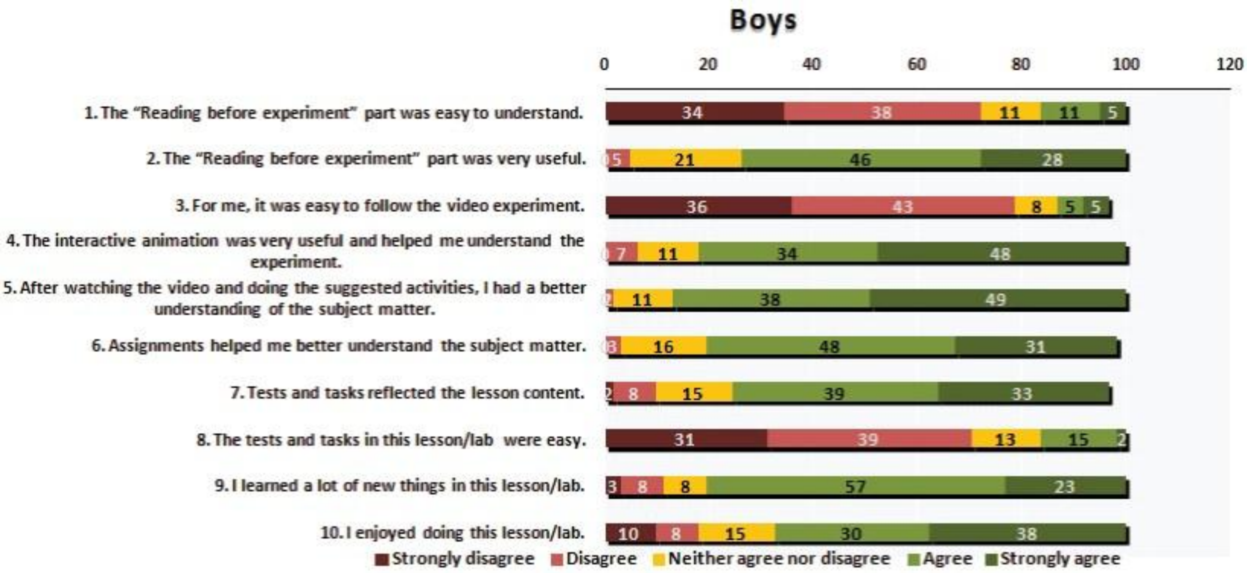


Figure 1: Student questionnaires for boys for the 1st Implementation Phase.

From the boys' chart it can be inferred that they had some difficulties to follow video experiments and the tests, tasks in the lesson. Yet, they gave positive answers for the rest of the questions. Most of them enjoyed the lesson, interactive animation and activities helped them to better understand the topic and they learned new things.

[1] Kurtköy Doğa Koleji, Çekirge Doğa School, Ankara Doğa School, Manisa Doğa School, Üsküdar Doğa School, Batman Doğa School, Ataşehir Doğa School, Kocaeli Doğa School, Bostancı Doğa School, Sarıyer Doğa School, Düzce Doğa School, Elazığ Doğa School, Denizli Doğa School, Ankara Doğa School, Beşiktaş Sabancı Anadolu Lisesi.
Ataşehir Doğa School, Acarkent Doğa School, Şişli Bomonti Doğa School, 30 Ağustos Female Vocational High School, Batman Doğa School, Üskü- dar Doğa School, Manisa Doğa School, Ankara Doğa School, Bostancı Doğa School.

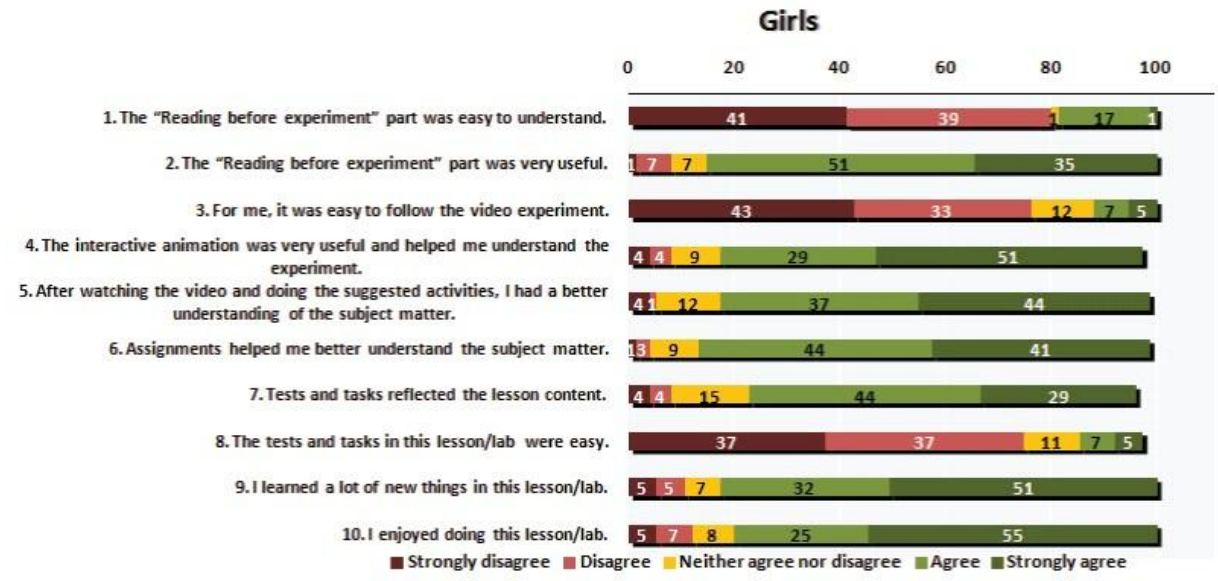


Figure 2: Student questionnaires for girls for the 1st Implementation Phase.

From the girls' chart it can be inferred that they had the same problems with boys. They had some difficulties to follow video experiments and the tests, tasks in the lesson. Additionally, only half of the girls found the "Reading before the experiment" part easy to understand.

The charts below (Fig.3-4) reflect views of high school students after the revision of lesson plans in the 2nd Implementation Stage. The second implementation phase covers the finalization of NTSE virtual laboratory, revision of the 9 experiments with all supportive educational tools according to inquiry based method, reinforcement of virtual experiments with Nano – kits and simplification and tailoring the guidelines for the lower grades between 10-13 ages. The questionnaires were conducted for 71 (52 girls, 19 boys) students studying at 9 different high schools between the age of 15-18[2].

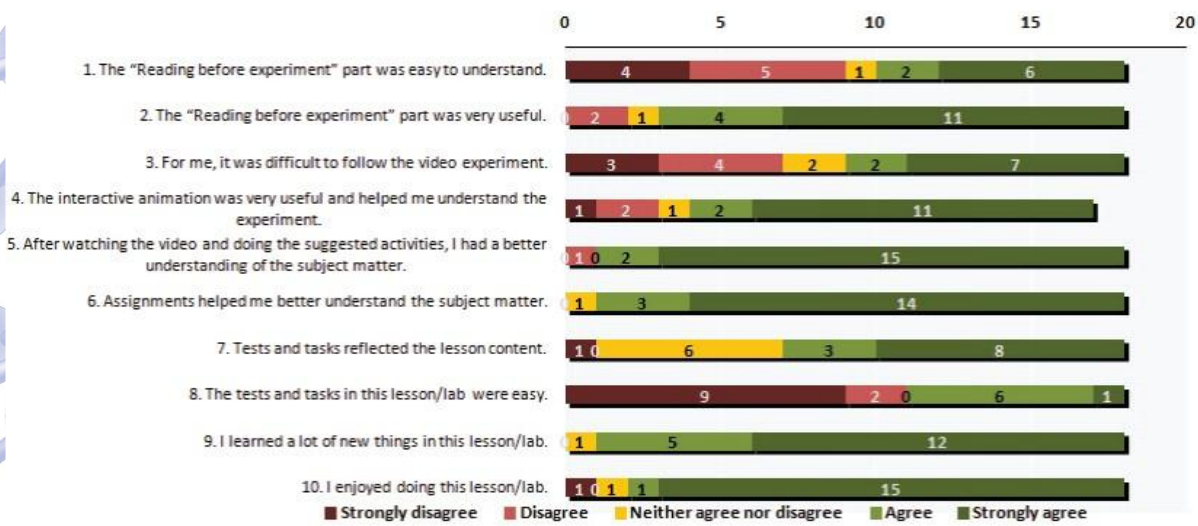


Figure 3: Student questionnaires conducted on September for boys studying at high school for the 2nd Implementation Stage.

[2] Ataşehir Doğa School, Acarkent Doğa School, Şişli Bomonti Doğa School, 30 Ağustos Female Vocational High School, Batman Doğa School, Üsküdar Doğa School, Manisa Doğa School, Ankara Doğa School, Bostancı Doğa School.

From the boys' chart it can be inferred that even though most of the boys found "Reading before experiment" part difficult to understand, they still thought that it is useful. As found out in the first implementation phase, following video experiment was still hard for students in the second implementation phase yet, they were able to better understand videos after using interactive animation and doing activities.

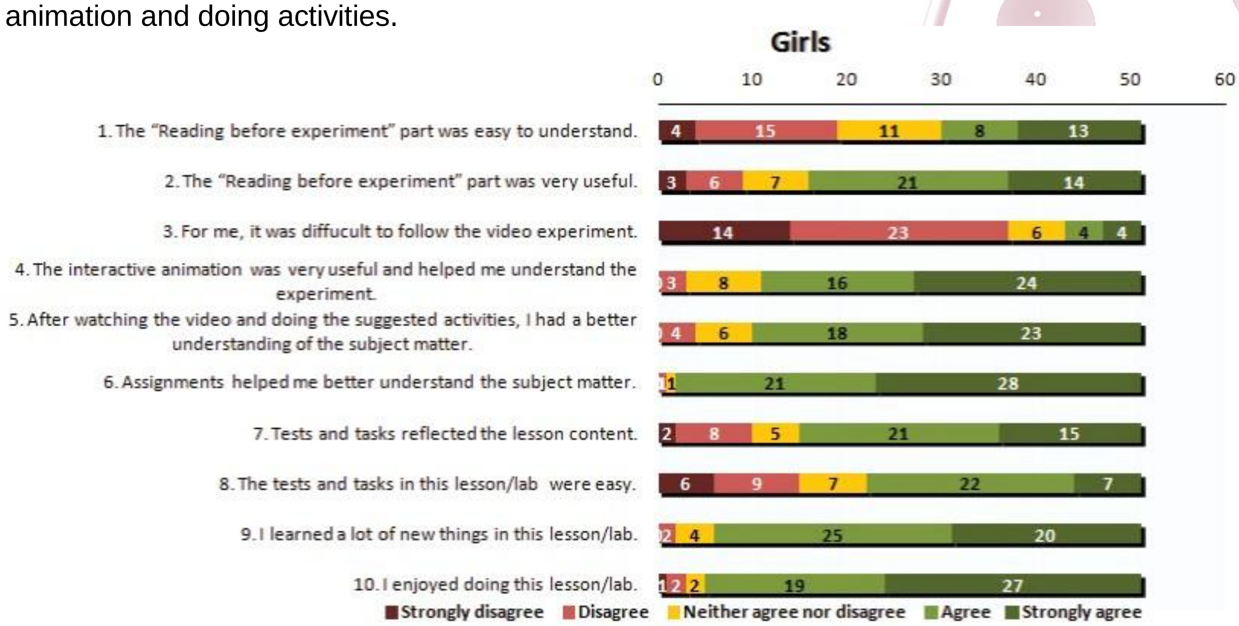


Figure 4: Student questionnaires conducted on September for girls studying at high school for the 2nd Implementation Stage.

Girls' ideas and thoughts about the lesson plans and experiments do not show a big difference from boys in the second implementation phase. However, most of the girls chose assignments as the best way to better understand the subject matter instead of videos or interactive animation.

The questionnaires were conducted for 42 elementary school students (20 boys, 22 girls) studying at 3 different schools (Halkalı Doğa School, Sarıyer Doğa School, Avcılar Doğa School). The age range of the students is between 10-15 years old. The questionnaires reflect the views of the students after simplification of the guidelines in our experiments room.

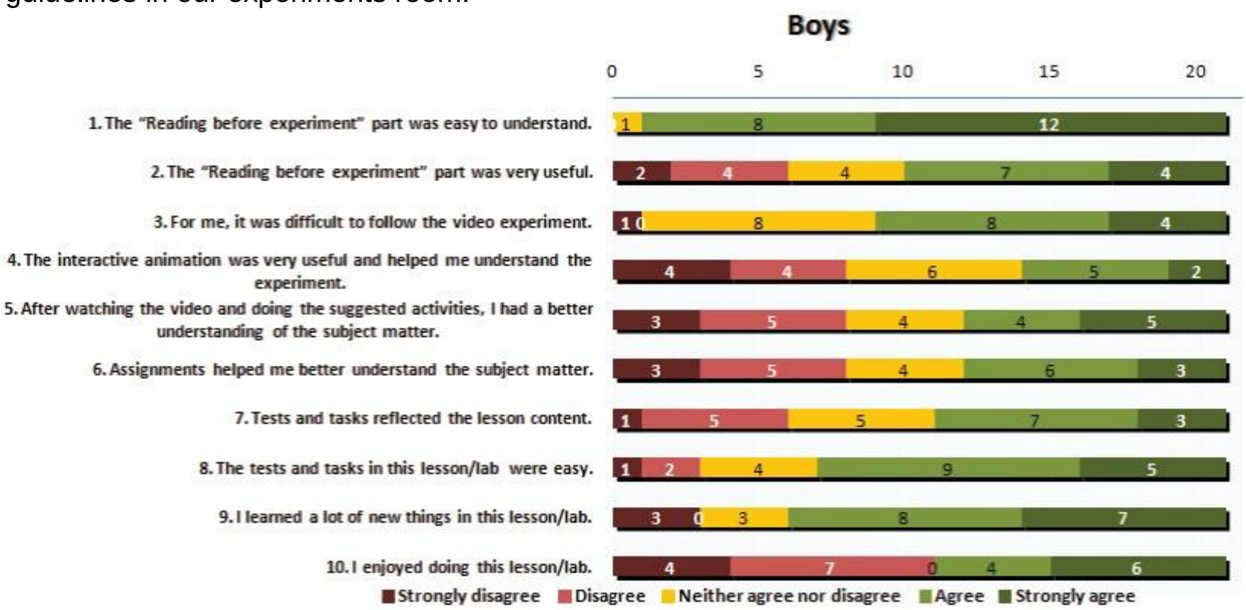


Figure 5: Student questionnaires conducted on September for boys studying at elementary school for the 2nd Implementation Stage.

The positive effects of changes made in the second implementation process are more visible when we look at the elementary school students' questionnaires. Compared to boys studying at high school, more boys found "Reading before experiment part" easy to understand and useful. It is obviously become easier to follow the video experiments and more of the students thought that tasks and tests in the lesson were easy.

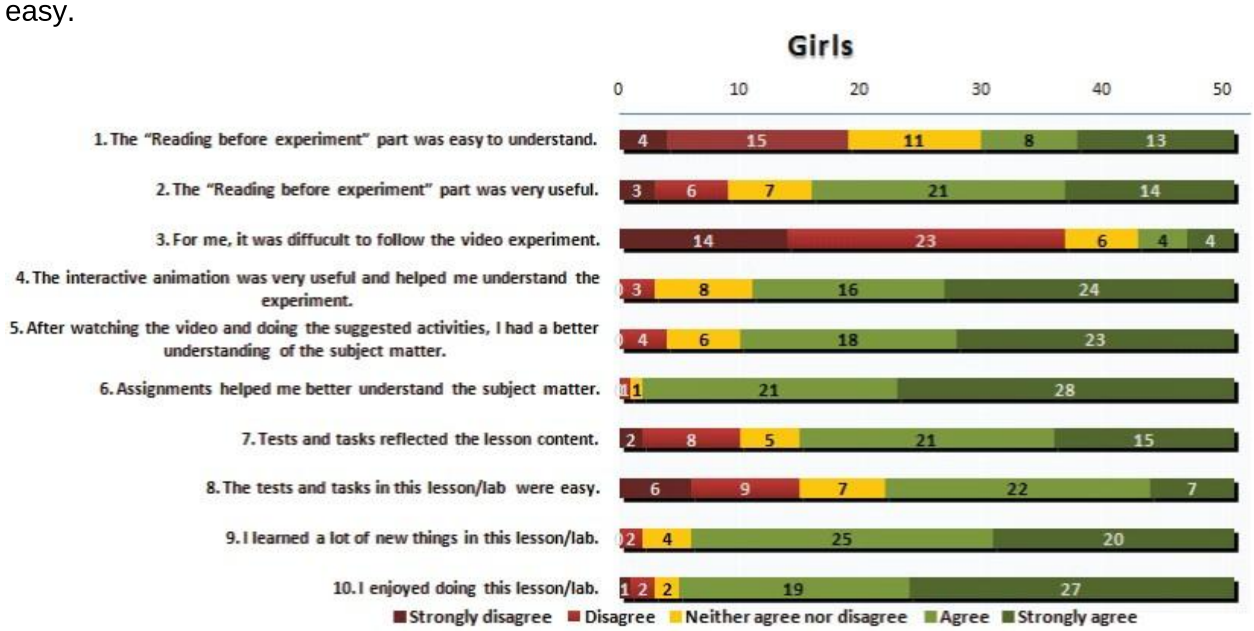


Figure 6: Student questionnaires conducted on September for girls studying at elementary school for the 2nd Implementation Stage.

It is observable that the changes made in the lesson plans and experiments also reflected in the girls under- standing of the lessons. Compared to the girls studying at high school, more girls found "Reading before experiment part" easy to understand and useful. It is obviously become easier to follow the video experiments and more of the students thought that tasks and tests in the lesson were easy. Different than the boys studying at elementary school, girls found it harder to follow the video experiments.

THEMATIC ANALYSIS OF THE TEACHERS' REFLECTIONS ON IMPLEMENTED LESSON PLANS

7 high school teachers and 4 elementary school teachers provided reflections on their classroom implementations. Their reflections were analyzed using the thematic analysis through defining the main and sub themes in their reflections. The data was analyzed by a content analysis approach. The content analysis is used in four stages to process the qualitative research data received from the documents: (1) coding the data, (2) identifying the themes, (3) arranging of codes and themes, and (4) identifying and interpreting the findings. Inductive coding is made in order to reveal the concepts, and the relationship between these concepts that underlay the data and themes are determined accordingly. The themes are placed under four topics during the analysis process: applicability, difficulty, enjoyment, curriculum match. In order to filter the data under four areas, uncertain expressions and repeats are eliminated. Each table is interpreted in accordance with the themes determined and an attempt is to define the impact of our educational

tools on the students and teachers. The results were listed according to their frequency. Some of the teachers gave more than one answers to same questions.

According to the thematic analysis of the Teachers' Reflection Questions; the videos, simulations (ICT tools) and hands-on activities are helping students to understand science better and relate it with real life. It is obvious that the experiments are well integrated with the science curriculum, so that the students can learn the topics more easily as well as raising their awareness in nanotechnology. The experiments with hands on activities, simulations, and videos are the most applicable tools and parts of the educational tools of the Virtual Laboratory for teachers.

On the contrary, traditional teaching in science education such as conversion of units is the most difficult part while implementing Nano Scale Lesson Plan. Apart from this, the language barrier in understanding videos and simulations are another obstacles in our Virtual laboratory. Time constraints in planning and implementing the lesson and mostly the hands on activities are another problems explained by teachers. It is observed that the obstacles are mostly about the logistic supports. Only one of them is about the content of the topic. But it totally proved that traditional teaching makes students learning more challenging and monotonous. This problem can be easily eliminated through revising the lesson plans in our Virtual Laboratory. Apart from this, it is useful to insert the notes for the teachers to let them modify the lesson plans according to the levels of their learners. Another problem about the language barriers can be sorted out with the translations. The time constraint in teaching is a big challenge for the teachers. Pre- planning the hands on activities and giving clear instructions before hands on activities can be the practical solutions to prevent this obstacle.

MAIN THEMES	SUB THEMES	FREQ	QUOTES FROM THE TEACHERS
APPLICABLE PARTS	Videos of the experiments	6	"The videos are very short and easy." to follow." "My students especially like sugar cubes activities."
	Hands on activities	4	
	Simulations	2	
	Conversion of units	3	
	Links with the real life implementations	1	
DIFFICULT PARTS	Conversion of units in traditional way	4	"It takes longer than I expected to plan and pre-pare the activities with the students. I spent at least 90 minutes for each lesson." "Our students had difficulty to convert the units in traditional way since it requires good mathematical skills." "Some of my students had difficulty to understand and follow the simulations in English. The language barrier hinders their learning."
	Language barriers while watching videos&simulations	3	
	Time constraints in planning and imple-menting hands on activities	2	
	Transitions of the activities from videos to simulations	1	
	New terms and topics about Nanotech-nology	1	
	Videos of the experiments	7	

ENJO YA BL	Hands on activities and use of Nano Kit	6	"Students were mostly impressed by videos of the experiments." "I observed that the students enjoyed to measure desks and chairs with with a nanoscale ruler."
	Simulations	4	
TOPICS MATCHED WITH THE CURRICULUM	Nano Crystal Fabrication, Iron Nano Particles and Ferrofluid match with Atomic structure	6	"Lesson materials were matched with chemistry Curriculum. The lessons will especially help students to learn atomic structure more easily." "Topics of conversion of unit, nanotechnology and state of matter are directly linked to lesson plans." "The Nano Crystal Fabrication Lesson Plan is in relation to the topics of atomic structure, scale and conversion of unit."
	States of matter	6	
	Understanding Nanoscale matches with the topic, The nature of physics:Scales	3	
	Conversion of Unit	1	

Videos of the experiments were highly voted educational tools in our Virtual Laboratory. Hands on activities and use of Nano kits are another enjoyable parts of teachers' implementations. Simulations are defined as the third enjoyable tools in their classroom implementations. The teachers believe that these educational tools are both applicable and enjoyable in their teaching since they reinforce students' learning and raise their motivation while implementing in their classrooms.

The last question shows that the topics of Atomic structure and States of Matter in Chemistry and Physics Education are the mostly matched with the Nano topics. These topics are Nano Crystal Fabrication, Nano Particles and Ferrofluid. Apart from this, the topic of Nature of Physics in Physics Curriculum is the second topic matched with the Nano scale topic. Conversion of Units is the last topic that can be matched with the Nano Scale topic. According to the results, all teachers found the matched the Nano Technology topics with their science education. So it is quite clear that the students' background knowledge in these topics supports their learning and make the topics easier and meaningful since they can find the connection with their previous learning.

METHODS AND RESULTS OF THE NTSE VIRTUAL LAB IMPLEMENTATIONS – GREECE

TEST IMPLEMENTATIONS

In total, seven implementations were conducted. Four teachers implemented the "Introduction to Nanotechnology/ Nanoscale" lesson plan in three state schools from October 2013 to December 2013. Total number of students: 157 (77 boys and 80 girls).

More implementations are planned in the Experimental School of Heraklion during this school year. The les- son plans to be tested are "Lotus effect" and "Buckyballs".

	Lesson plan	Deviations from lesson plan	School	Grade	Date	Teacher	Students	Boys	Girls
1	Nanoscale	No	High School, Argiroupoli Rethymnon, Crete	10th	Oct. 2013	Ioannis Sgouros	16	10	6
2	Nanoscale	Yes	2nd Gymnasium Heraklion Crete	8th	Nov. 2013	Theodora Katsiouli	22	11	11

3	Nanoscale	Yes	2nd Gymnasium Heraklion Crete	8th	Nov. 2013	Theodora Katsiouli	22	10	12
4	Nanoscale	Yes	2nd Gymnasium Heraklion Crete	8th	Nov. 2013	Paraskevi Ktistaki	24	13	11
5	Nanoscale	Yes	2nd Gymnasium Heraklion Crete	8th	Nov. 2013	Paraskevi Ktistaki	22	10	12
6	Nanoscale	Yes	Experimental Gymnasium Heraklion Crete	9th	Dec. 2013	Ioannis Karadamoglou	25	17	8
7	Nanoscale	Yes	Experimental Gymnasium Heraklion Crete	9th	Dec. 2013	Ioannis Karadamoglou	26	6	20
Totals:						4	157	77	80

General Remarks

The aim of all implementations was to introduce nanotechnology and nanoscale to the students by using the material provided in the Virtual Lab. The lessons' objectives were:

- To increase awareness about nanotechnology
- To comprehend nanoscale
- To enhance the ability to convert units into nanometres

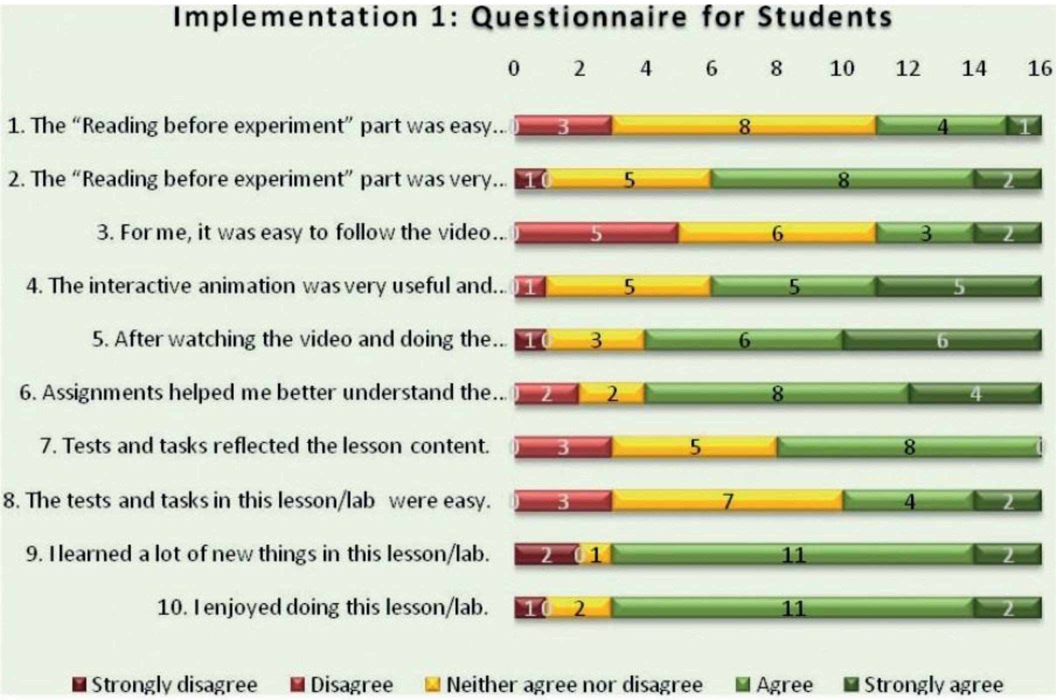
The students were provided in advance with the "Student's Guidelines" booklet. The duration of the lessons was 45 minutes. At the end, all students and their teacher filled in questionnaires and assessment grids. The questionnaires aimed at evaluating and collecting information and suggestions on the content, usability and pedagogical effectiveness of the NTSE Project teaching materials (video, interactive animation, teacher guidelines, student guidelines).

1st Implementation – High School of Argiroupoli, Crete

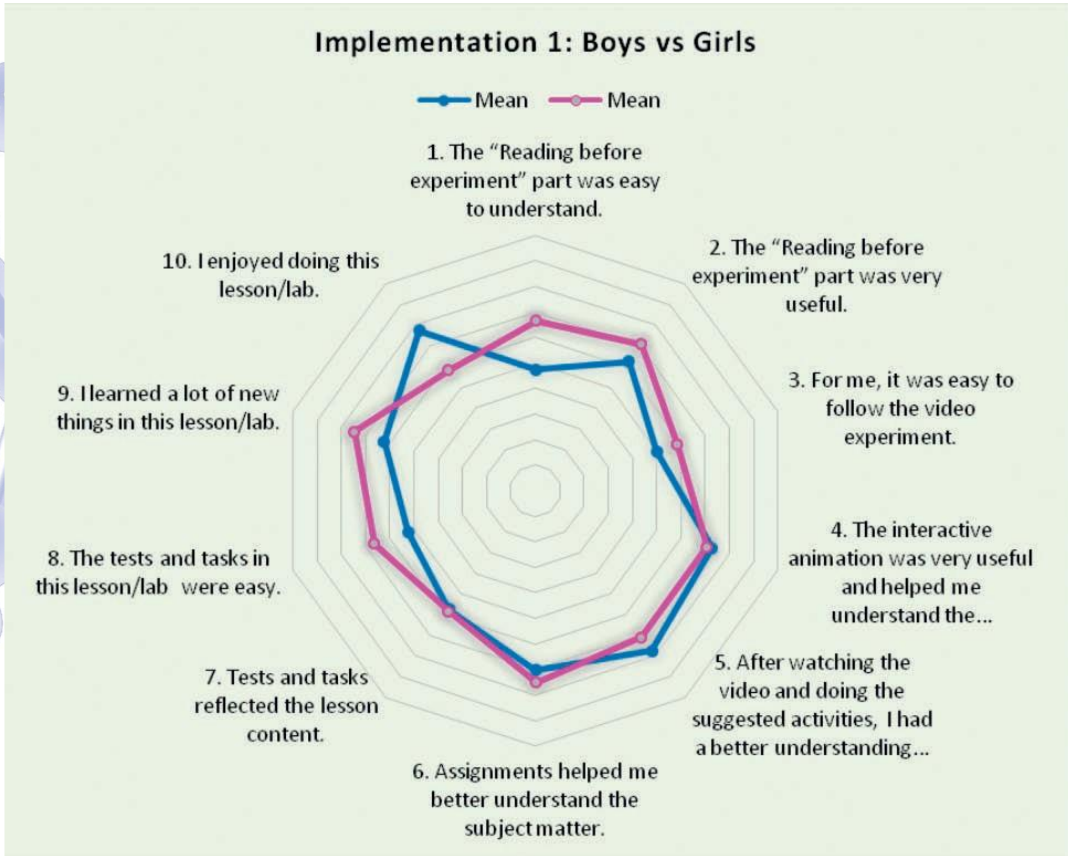
The first implementation was conducted in a high school class (10th grade) of 16 pupils in Argiroupoli, Crete. Argiroupoli is a village in an agricultural area in western Crete. Students from this high school participated in the nano poster competition. The physics' teacher, Ioannis Sgouros, participated in the nanocamp as a Greek expert since he is a PhD student (Teaching nanoscience in Secondary Education, Pedagogical Department, University of Crete).

No deviations from the lesson plan, as described in the teacher's guidelines booklet, were made.

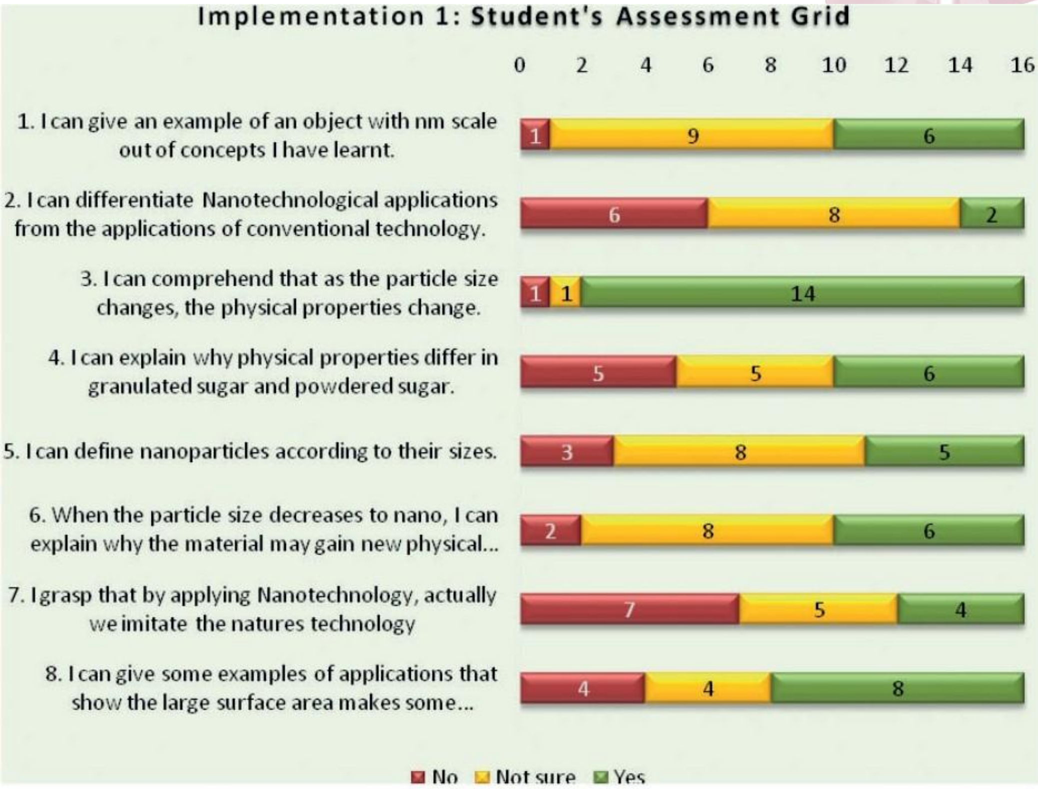
Impact on students



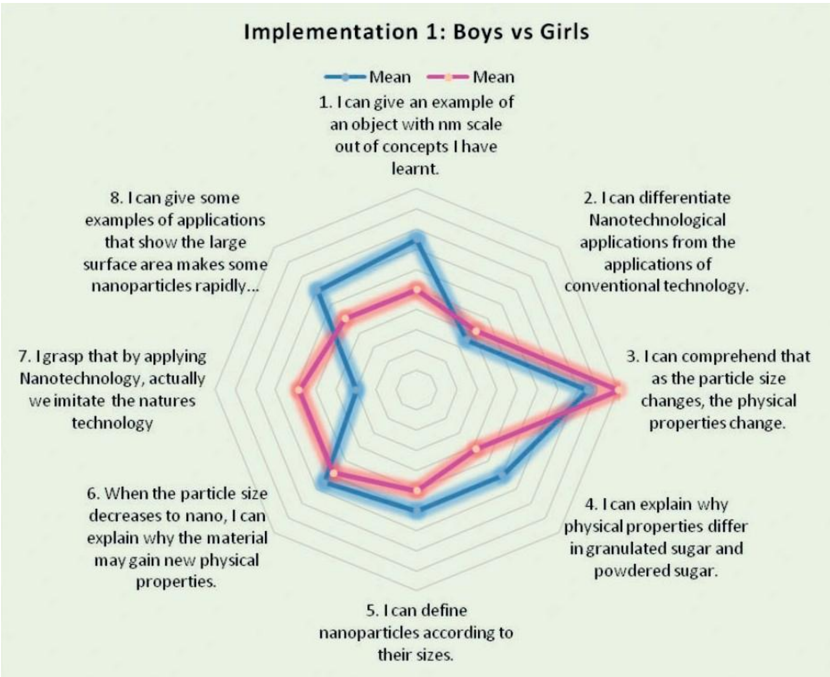
According to students' views, they enjoyed the lesson and learned many new things. The video as well as the assignments, helped them understand the nanoscale. On the other hand, they did not find the "Reading before experiment" part easy.



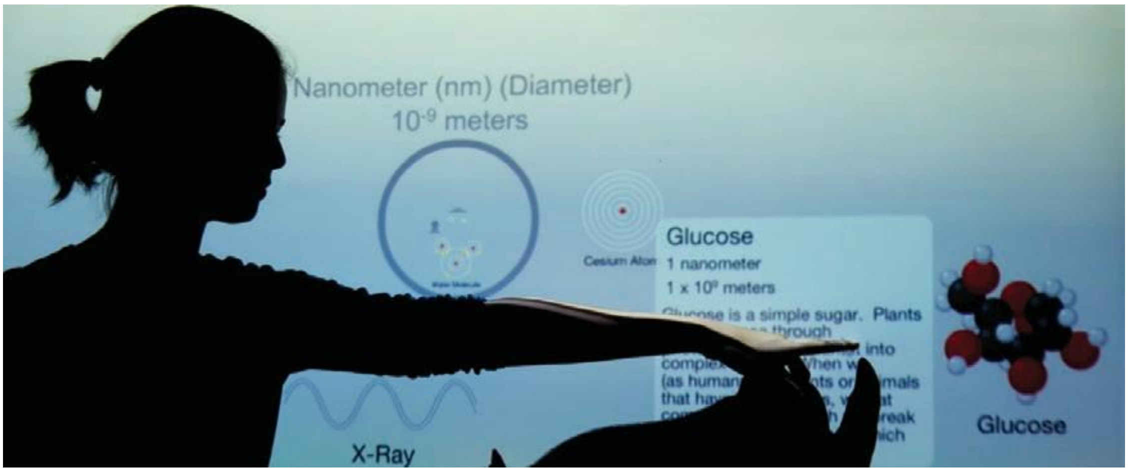
There are no significant differences in views between boys and girls. The boys seemed to enjoy the lesson more while the girls found the “Reading before experiment” part and the tests easier.



Students comprehended in a high degree the relation between particle size physical properties. They experienced difficulties in differentiating nano applications from conventional technology applications.



Boys found it easier to give examples of objects on the nanoscale and nano applications related to size/volume ratio. On the other hand, girls had a better grasp of the idea of biomimicry.

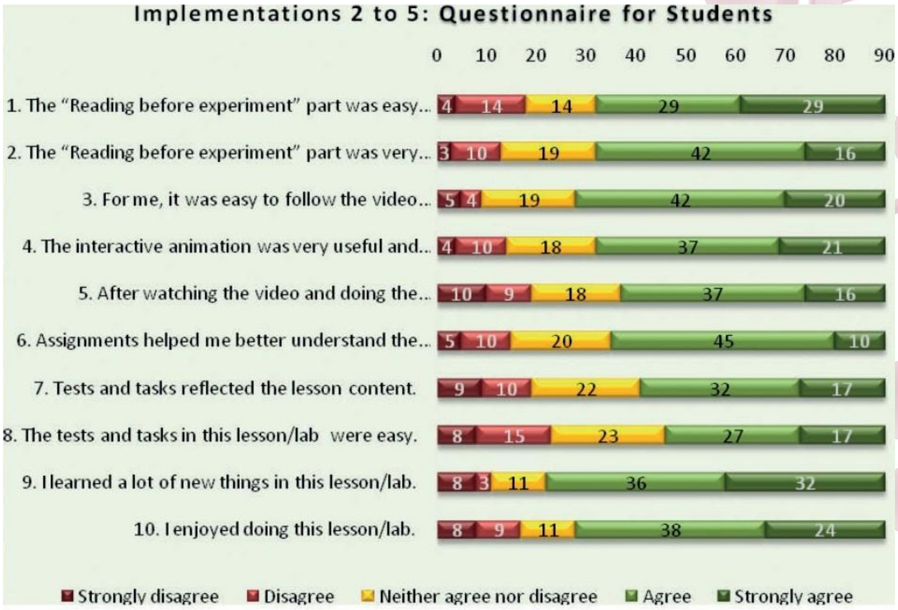


Implementations 2 to 5: 2nd Gymnasium of Heraklion, Crete

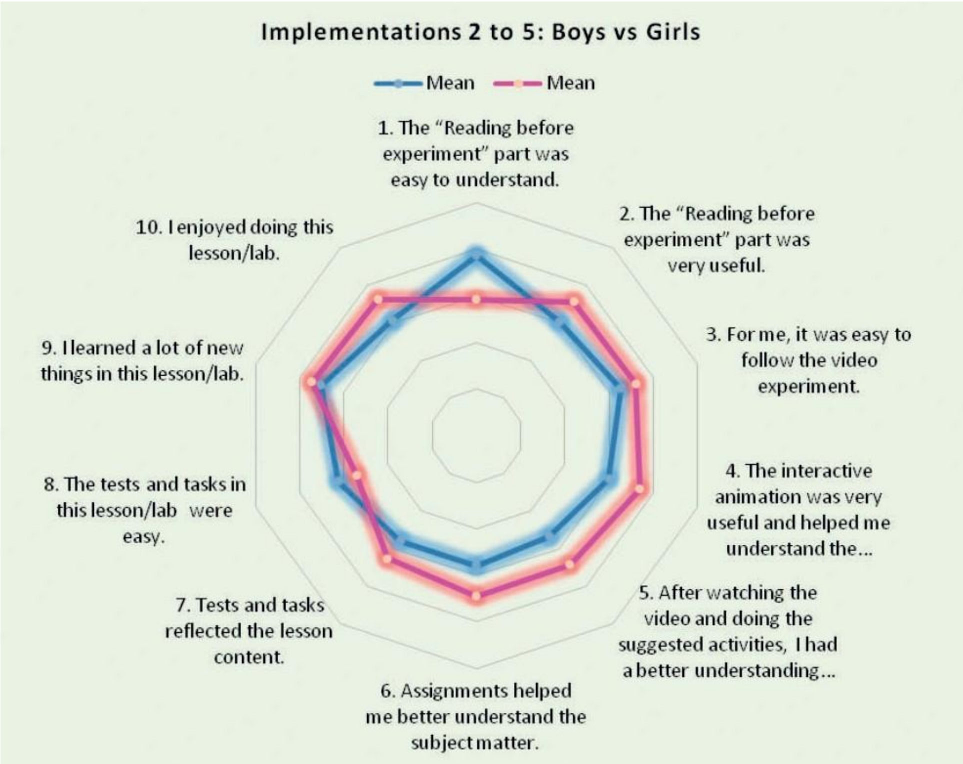
Those implementations were conducted in four classes (8th grade) with 90 students in total. The Second Gymnasium of Heraklion is a school with a very good reputation in the city of Heraklion, Crete. According to data gathered from the school, the average score of these four classes in physics and chemistry is 16.2/20.

The school was very active during the nano poster competition since eight groups of students participated in the competition. The winning poster for Greece came from this school. Four students (older than those participating in these implementations) along with the headmaster took part in the nanocamp in July, 2013.
There were some deviations from the original lesson plan:

- The video "Powers of Ten" was not used due to time constraints. Emphasis was given to "Scale of the Universe II" interactive application.
- A PowerPoint presentation titled "Introduction to nanotechnology" was used.
- Two videos showing nanotechnology applications (nano-coating) and future materials (buckypaper) were also used

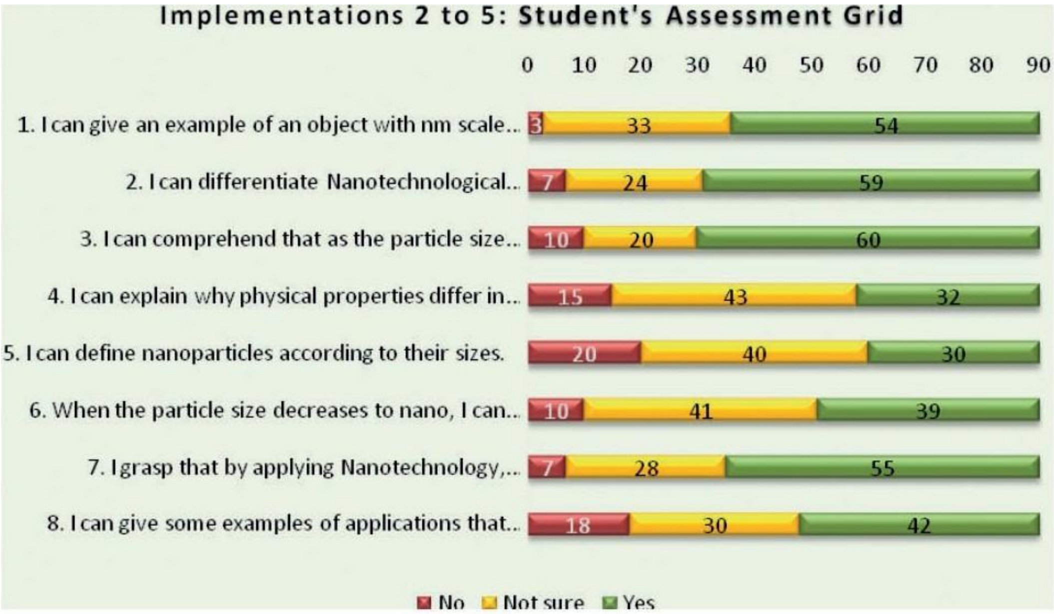


Students enjoyed the lesson and learned many new things. But 4:10 of them had difficulties with the tests. In general, they seem to have a good grasp of the subject.

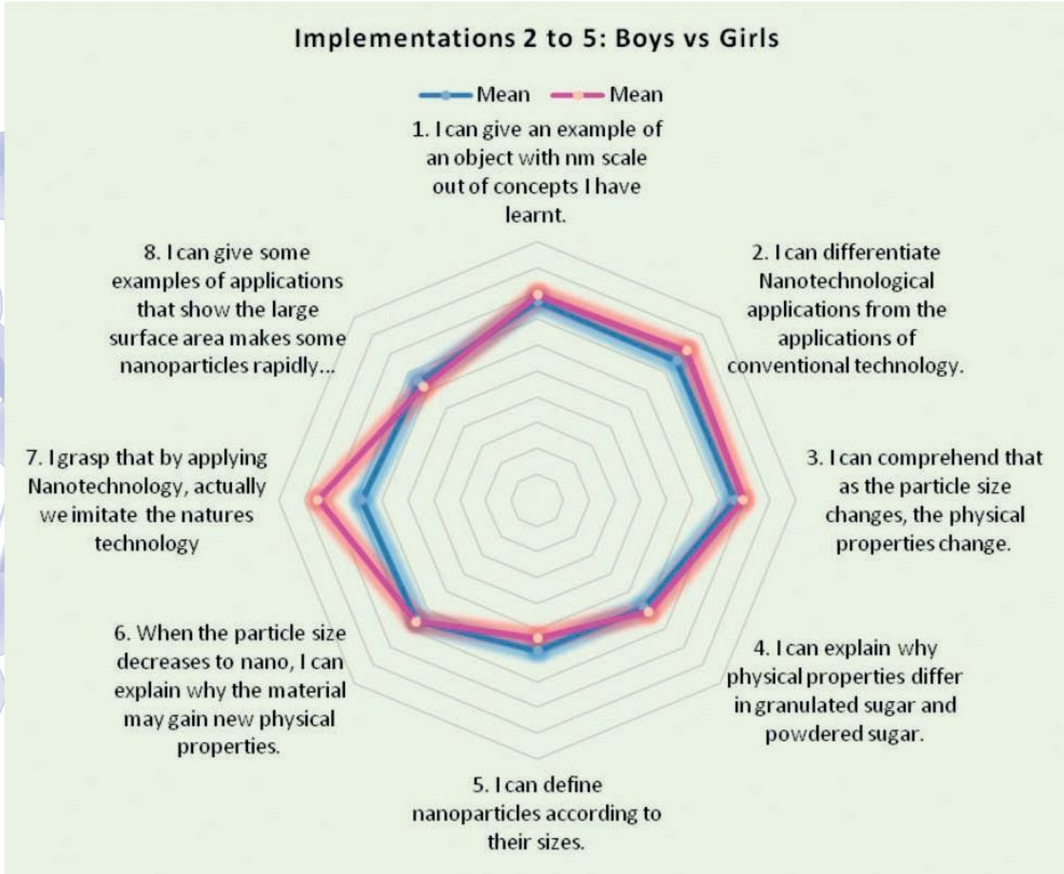


Girls scored significantly higher in most statements even if they had more difficulty with the "Reading before the experiment" part than the boys.

Impact on students



Difficulties in defining nanoparticles and explaining the relation between physical properties to size/volume ratio were observed.

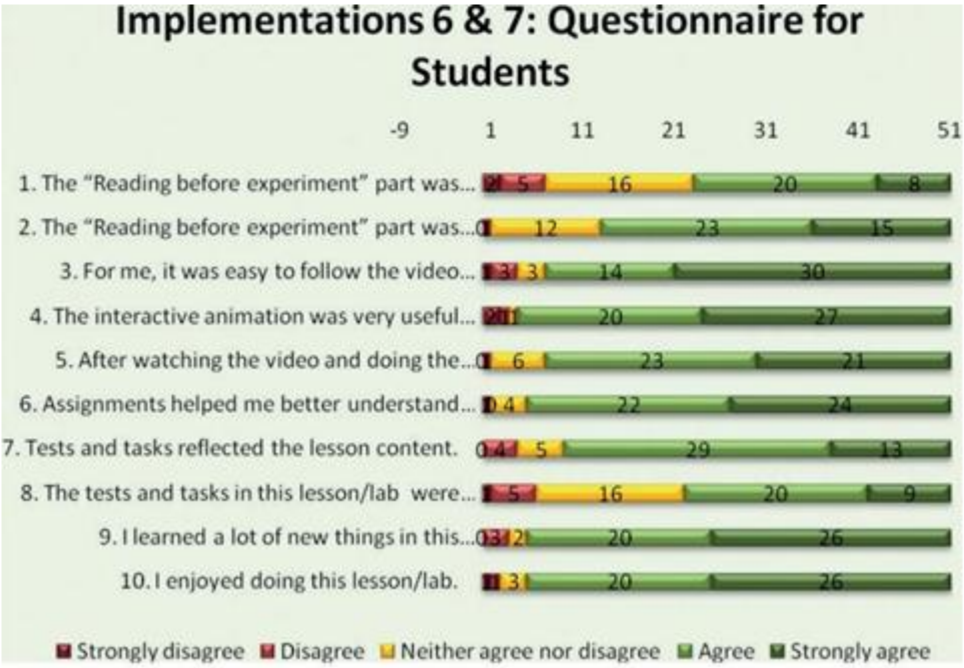


No significant differences in comprehension of nanoscale concepts were noted except that girls comprehended the concept of biomimicry better.

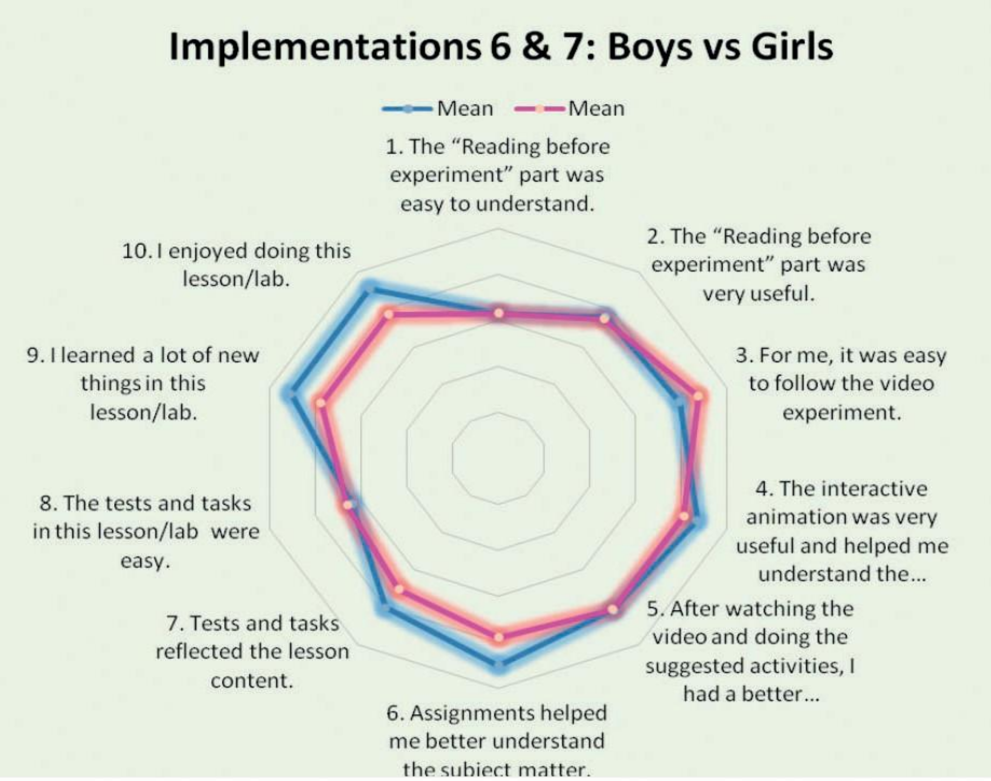
Implementations 6 and 7: Experimental Gymnasium of Heraklion, Crete

The implementations were conducted in two classes (9th grade) with 51 students in total. The Model Experimental Gymnasium of Heraklion is an elite school in Heraklion district. Students gain entry through an entrance exam that has recently been implemented. All classrooms are equipped with interactive whiteboards.

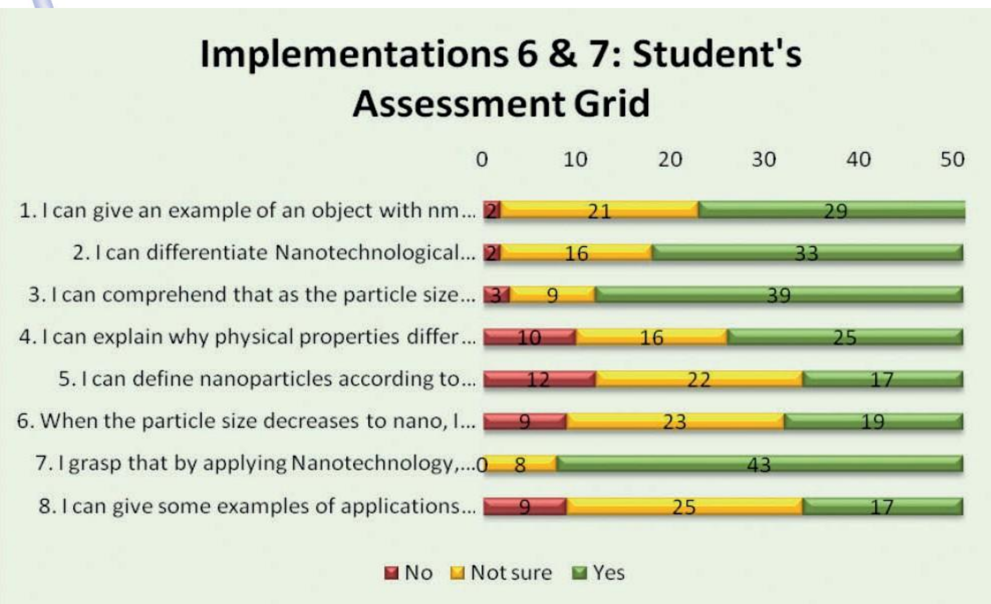
Deviations were made from the original lesson plan: As per implementations 2 to 7. In addition two short videos showing differences in burning behavior between a conventional film-forming latex film and a polymer-silica nanocomposite film were used.



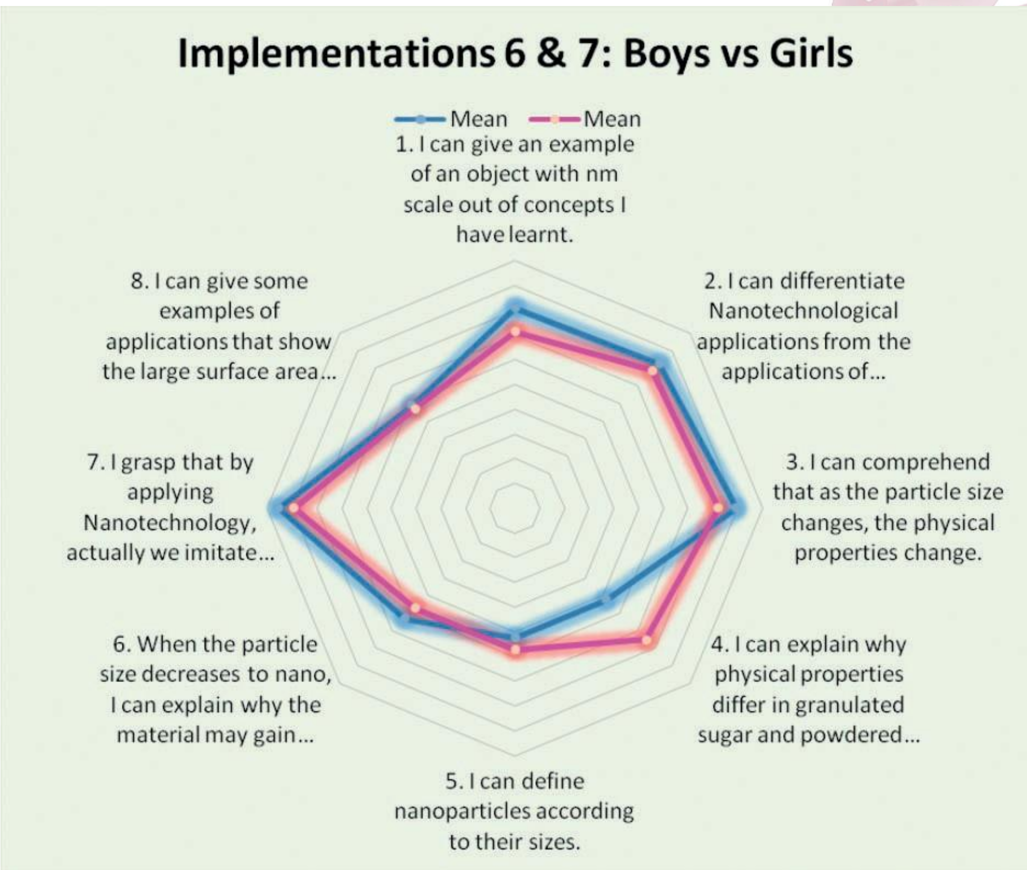
High scores on all indicators regarding the lessons were observed. Again the "Reading before the experiment" part and the tests caused difficulties for some students.



Boys scored slightly higher on some statements.



Again difficulties in connecting physical properties to size were experienced.



Boys found it difficult to explain why physical properties of granulated sugar differ from powered sugar.

BASIC DESCRIPTION OF THE METHODS OF IMPLEMENTATION & MAIN RESULTS OBTAINED AFTER THE IMPLEMENTATION PROCESS-ITALY

In Italy, the process of NTSE Virtual Lab implementation has been carried out in some schools involving teachers and pupils. In those contexts, the roles of local experts in the test-implementation process consisted on the organizing of the whole process of implementation in collaboration with the involved teachers to realize 3 Case Studies and 3 implementations in videoconference. Being a quite new topic for science communicators and educators, we asked our experts also to support before and during the activities (introducing the topic, stimulating their creativity, moderating the process, gathering the data, telling their experience to friends and family members).

Five classes, six teachers and around 120 pupils have been involved in the implementation process in the period April – December 2013:

- Classe IV (12th degree) – Liceo Scientifico Statale Tito Lucrezio Caro di Sarno (NA);
- Classe III (11th degree) – Liceo Statale Giuseppe Mazzini di Napoli;
- Classe IV (12th degree) – Liceo Scientifico Statale Arturo Labriola di Napoli;
- Classe III (11th degree) – Istituto Superiore Carlo Cattaneo di Volla (NA);
- Classe V (5th degree) – Scuola Primaria San Tarcisio di Ercolano (NA).

The subjects of implementations in ITALIAN classes were:

- A presentation of NTSE project and a general introduction to the subjects of nano sciences and nano-technologies through the implementation of the contents of the lesson plan *"Understanding nanoscale"* developed for NTSE's Virtual Lab (every involved class);
- Lesson plan *"Lotus effect"* (Liceo Mazzini, Liceo Labriola, Scuola Primaria San Tarcisio);
- Lesson plan *"LED, Light Emitting Diodes"* (Istituto Superiore Cattaneo).

Three case studies related to the carried out experiences were developed by the teachers of the classes listed above (Liceo Mazzini, Liceo Labriola, Istituto Superiore Cattaneo).

The lesson plans dealt in the implementation phases have been chosen because we considered them the most appropriated for several reasons:

- "Understanding nanoscale" or, at least, its more significant topics have been proposed to every involved class because it was necessary to provide teachers and pupils with an adequate background about nano world;
- "Lotus effect" has been chosen because its contents were considered both by the experts of Idis and the teachers the most enjoyable and amazing for the pupils, easy to reproduce and related to daily life;
- "LED, Light Emitting Diodes" has been chosen in just one case being the involved school (Istituto Cattaneo) vocationally aimed to technical subjects and its student were already skilled in such subjects as electricity and electronics.

In the large majority of the cases, the teachers have been contacted by the experts of Fondazione Idis to involve their students in the nanocompetition (see chapter VI) happened in spring 2013. The experts presented to the teachers the lesson plans available in the Virtual Lab and then they agreed together about the Lessons to be implemented with the classes.

The responses expressed by all the involved stakeholders have been generally very positive, as showed by the results of the assessment grids resumed below as well as by the comment of the teachers.

Concerning the primary school involved in the experience, it is to be specified that even if the lesson plans developed in the framework of the project were addressed to students from 8th to 13th degree, the partners decided to involve also some children classes in order to explore the flexibility of the lesson plans. In particular, in the implementation carried out in Italy it has been chosen the "Lotus effect" because the expert and the involved teacher considered it the most enjoyable for such young pupils, as already said above.

Moreover, three videoconferences where the contents of the mentioned lesson plans were implemented together with classes of other countries among the ones involved in the project:

- Scuola Primaria San Tarcisio – a primary school class from Doga School (TR), (spring 2013);
- Liceo Scientifico Labriola – a high school class from Doga School (TR), (spring 2013);

Scuola Primaria San Tarcisio – a primary school class from "Ioan Alexandru Bratescu Voinesti" School Targoviste (RO), (December 2013).

Concerning the videoconference, we have to report that just three have been effectively carried out even if more were been planned, and this for several reasons comprising the lack in adequate ITC equipment of the schools as well as the difficulties to arrange an appointment between two classes when schools are very busy in their cur- ricular activities.

Assessment of the results of the implementations

The lesson plans implemented in the schools have been mainly assessed asking the pupils to fill the grids specifically fitted. The grids have been filled just by the older pupils from high and vocational schools, being them specifically designed for their ages.

The gathered results are shown below. It is to be considered that the results upcoming from both the lyceum classes have been joined together being related to the same lesson plan (Lotus effect) while the ones upcoming from the vocational school – related to LEDs – have been elaborated apart.

Lotus effect (Liceo Scientifico Labriola and Liceo Mazzini)

Even if joined and shown in only one sequence, the results gathered for each question from both the classes are very similar and then comparable.

The large majority of the students agree with the first three statements. These results can be explained con- sidering the previous skills of the students.

Also in this case we can see a very large majority of the students agreeing with the statement. Anyway we have to consider that the statement concerns an hypothetical future experience the students could deal, therefore not everybody is sure to see a lotus flower in the future.

Just the pupils from Liceo Labriola answered to this question while the ones from Liceo Mazzini didn't dealt this topic and therefore they didn't give a response. This the reason with the anomalous numbers.

The students got information about the subject of this statement just from the Student's Guidelines having not any other information about water walking insects. However the large majority of them agree with the statement.

The results of this statements are more heterogeneous. Notice that the whole sentence contains two different statements, this could explain the resulting uncertainty.

As for the previous, also this sentence could be split in two different statements with different meanings. Anyway the majority of the interviewed students agree with the sentence.

LEDs, Light Emitting Diodes (Istituto Superiore Cattaneo)

An absolutely large majority of the student expresses a positive response due, may be, from their previous skills deriving from their curricular background. This question shows less sharp results that could be explained consid-ering its contents more scientific and less technically related.

The largely positive results can be explained considering the confidence the pupils have with formulas applied in electronics.

A significant number of pupils answered "not" to this statement. In this case they honestly acknowledge they understood "what happen" but not "why".

The large majority of positive responses could be explained considering the effectiveness of some practical experiences proposed in the lesson plan.

In the lesson plan the subject of this question is dealt in a way similar to the one adopted in usual frontal lessons at school. This can explain the significant number of responses as "not sure" or "not".

Concerning the implementation of the Lesson Plans in Italy, we can notice a general positive outcome. The information and the educational tolls provided by the Virtual Lab can be effectively exploited adapting them to the educational needs of the involved classes.

BASIC DESCRIPTION OF THE METHODS OF IMPLEMENTATION & MAIN RESULTS OBTAINED AFTER THE IMPLEMENTATION PROCESS-ROMANIA

In Romania, the process of NTSE Virtual Lab implementation was carried out in schools (involving teachers/ pupils) and university (involving university students/prospective Science teachers, master students and PhD students (researchers)). In those contexts, the roles of local experts in the test-implementation process consisted on the organizing of the whole process of implementation and assuring the necessary logistic (e.g. designing the *Lesson Plans, Laboratory Sequence of Events*) and collaborating with promoters (teachers, university staff, PhD students) for realizing *5 Case Studies*. At the same time, the experts offered the necessary support *before* and *during* the designed activities (moderating the implementation process, leading the discussions, presenting scientific information), and also they disseminates the NTSE project and emphasized on the importance of the NTSE Virtual Lab implementation to the education community and local mass-media.

At the pre-university level, four schools (“Vasile Carlova” School Targoviste, Gimnasium School Gura-Sutii, “Bal- asa Doamna” High School Targoviste and “Ion Alexandru-Bratescu Voinesti” School Targoviste) have been involved in the implementation process in the period April – December 2013. During the implementation process, 7 teachers, 6 university experts & 100 pupils took part in the “school test-implementation” phase, at the 3rd, 7th, 8th and 9th school grades.

The subjects of implementations in Romanian classes were:

- *“Nanotechnology as Future Technology”* that included parts from *“Nanoscale and Nanotechnology”* teach- ing materials uploaded in the Virtual Lab;
- *“Nanotechnology and Nanobiomimicry”* that included the Virtual Lab clips: *“Understanding Nanoscale”* and *“Lotus Effect”*, but also the related teaching materials;
- *“Allotropes of Carbon. Are there any Buckyballs?”* that included the Virtual Lab clips: *“Understanding Na- noscale”* and *“Making Origami Buckyball”*, but also the related teaching materials;
- *“Is there any Lotus Effect around us?”* that included the Virtual Lab clips: *“Understanding Nanoscale”* and *“Lotus Effect”*, but also the related teaching materials.

The lessons designed for the secondary education level sought to develop the knowledge, skills and attitudes of students involved, so that they can participate effectively in discussions on topical issues. They stressed the direct exchanges of ideas and experience, for students involved in the project, to take a clearer picture of the investigative approach in action. In this respect, the objectives were the following: increasing the interest of students towards civic issues as well as to the scientific findings; training the young people to express their views on various Science issues; acquiring by students of investigative capacities and skills; stimulating students’ desire to understand the current problems of the actual society; increasing the students’ confidence and their self-esteem to be involved in the discussion of issues that can be found in ordinary newspapers.

From the scientific point of view, the lessons activities allowed students to learn about the defined characteristics of;

- certain physical systems encountered in the wild;
- nanotechnologies phenomena;
- possibilities of practical application related to theoretical knowledge of nanotechnologies;
- phenomena in the field of nanotechnologies;

- physical characteristics of the phenomena in the field of nanotechnologies;
- causal existed relations;
- carrying out the physical phenomena specific to nanotechnologies;
- application of the knowledge gained through the study of Science in related fields;
- presentation (in written or oral form) of the results of an investigate approach using specific science terminology;
- advantages and disadvantages of nanotechnologies from the environmental perspective.

The classroom management and the sequence of events were decided by each teacher according not only to the chosen topic, but also to the students' level and knowledge. As procedural resources, the following teaching and learning methods and processes can be emphasized: presentation, conversation, observation, explanation, exercise, discussion, experimentation, modeling, deliberation (also including the SAC Method – Structured Academic Controversy). As class activities organization, both group and individual forms of organization were applied. Concerning the material resources used during the implementation process, video-projector, flipcharts, media texts, PCs, Internet, sticks and modeling clay, teaching materials and learning sheets developed by the teachers can be enumerated.
At the university level, 5 university staff (project experts), 45 university students (second year of study on Faculty of Science and Arts & Faculty of Environmental Engineering and Food Science), 25 master students and 8 PhD students took part in the university test-implementation phase. The implementation process took place in April- November 2013 and was organized the Science Department laboratories and halls.
The subjects of implementations were: "Nanoparticles/Nanomaterials – Small Things behind a Stunning World", "Nanofibers" and "Deposition of TiO2 Nanoparticles on Optoelectronic Materials for Achieving Dye-Sensitized Solar Cells" which led students to explore the NTSE Virtual Lab and consult materials from NTSE Repository along- side other scientific materials from the university library and international databases.
The role of Valahia University Targoviste local experts in the process of test-implementations organized at the university level was oriented on: organizing the process of implementation and assuring the necessary logistic (VL videos & repository materials, additional resources, materials for laboratory activities); offering support in the developed activity (leading the discussions, presenting scientific information) and collaborating with master students / PhD researchers to meet their needs / requirements.

In completing the activities, university students, as well as master and PhD students, developed a variety of process skills critical to their further specialization including: working collaboratively; interpreting and prioritizing data / information; acquiring (by students) of investigative capacities and skills; defending an argument; increasing their confidence and self-esteem to be involved in the discussion of scientific issues that can be found in specialized newspapers and scientific journals; experimenting and obtaining reliable results.

From the scientific point of view, the proposed activities allowed students to learn about the defined characteristics of:

- nanotechnologies phenomena;
- possibilities of practical application related to theoretical knowledge of nanotechnologies;
- phenomena in the field of nanotechnologies;
- physical characteristics of the phenomena in the field of nanotechnologies;
- causal existed relations;
- carrying out the physical phenomena specific to nanotechnologies;
- application of the knowledge gained through the study of Science in related fields;
- presentation of the results of an investigative approach using specific Science terminology;

- advantages and disadvantages of nanotechnologies from the environmental perspective;
- new working methods and various tools of analysis.

Concerning the classroom management and sequence of events during the implementation stage at the university students' level, before the starting of activity, students should understand that many materials that belong to the natural world have properties which are the result of inherent nanostructures. The interaction of light, water and other materials with such nanostructures gives natural materials special properties that we can see with your own eyes. Nano- materials study shows an increased interest in scientific research in recent decades. These materials, which are characterized by very small particle size, have great potential for use in many industrial applications, biomedical, electronics, etc. Alternatively, the instructor / teacher could present them some of the basic concepts concerning "nano" term and experimental examples by using appropriated images and videos. The students from each team must share interesting facts and ideas found in the documented text, in order to arrive at a better understanding of the analyzed documents. It was recommended to start the documentation from the experiments proposed in the NTSE Virtual Lab (http://vlab.ntse- nanotech.eu/NanoVirtualLab/) and completed by using the NTSE Repository (http://ntse.ssai.valahia.ro/).

As a guideline for students the activity was divided into six "sessions" (as is foreseen in Table 1), some inside laboratory and some outside laboratory.

Sequence	Location	Activities
Introduction and Session 1	Chemistry lab (50–90 min)	The teacher / instructor facilitates students discussion about nano terms. Students split into work teams (7 work teams formed by 4–5 students) and receive scenario / task and data and brainstorm potential main experiment to be made
Session 2	Outside lab	Teams asses information and search for additional information
Session 3	Outside lab	Teams outline and produce drafts of essays
Session 4	Chemistry lab (30–40 min)	Teams present preliminary drafts to the teacher and verify for reagents, materials etc. in order to be available for experimental work
Session 5	Outside lab	Teams revise products according to reviewers' suggestions
Session 6	Chemistry lab (90 min)	Teams present products to entire group Each team reviews and evaluate one other team's designed experiment. The experiment selected (in terms of structure, didactical approach, scientific notions etc.) is made by all teams

Table 1. Sequence of Events

Related to procedural resources, the following teaching and learning methods and processes can be emphasized: experimenting, explanation, observation, conversation, discussion, deliberation. The organization of class activities included individual activities, group work and frontal discussions. Concerning the material resources used during the implementation process, video-projector, flipcharts, media texts, PCs, Internet, teaching materials and learning sheets developed by the project experts, Colloidal Chemistry laboratory resources (instruments, glassware, reagents, utilities etc.) were used.

When acquiring the information and after realizing the activities, students had to be able to:

- edit a report/essay where to submit arguments in respect of decisions taken and the related reasons;
- identify the consequences of applying nanotechnologies to human health, environment and society;
- retrieve specific information in the proposed websites;
- analyze selected information in relation to the proposed objectives;

- decide as a team how to deliver structured information in terms of didactical and pedagogical issues (terms, notions, experimental stages);
- analyze the pros and cons of applied nanotechnologies;
- submit collective conclusions made in front of the colleagues, in the laboratory.

As it was mentioned before, one of the results of the test-implementation phase was the development by the Romanian partner of *5 case-studies* emphasizing the use of different facilities of NTSE Virtual Laboratory during the practical activities organized at lower secondary school students, upper secondary school students, university students (prospective Science teachers), master students and PhD students.

Two of those case-studies were developed during the implementation of two experiments from Virtual Lab

on the level of lower and upper secondary school students: (*"Allotropes of Carbon. Are There any Buckyballs?"* – Teacher: Nadia Bădoiu, Gymnasium School, Gura-Șuții, Romania (using the Buckyball Experiment of VL) and *"Nanotechnology and Nanobiomimicry"* – Teacher: Carmen ANTONESCU, Bălaşa Doamna High School, Târgovişte, Romania (using the *Lotus Effect Experiment* of VL).

The first case study – designed for lower secondary education (8th form) – introduced and explained the *allotropes of carbon:* diamond, graphite, fullerenes, carbon nanotubes, amorphous carbon. During the activity, students learned about the defined characteristics of: (i) allotropes of carbon; (ii) structure of buckyball (fullerenes); (iii) application areas of buckyballs (fullerenes) and buckytubes (carbon nanotubes); (iv)different covalent bond structures of carbon; (v) crystal structure of allotropes of carbon.

In the beginning of the lesson activity, the students watched a *ppt presentation* (prepared by the teacher), in which the concepts of *Nanotechnology* and *Nanoscale* are introduced and discussed. After that they became more familiarized with the topic by using Virtual Lab resources (*Understanding Nanoscale* and *Carbon Nanotubes*) and *Nano Repository* ones, but also an animation related to *The Scale of the Universe 2* (http://htwins.net/scale2/). Then, the teacher made the connection between *Nanotechnology / Nanoscale* and the *allotropes of carbon,* using an interactive ppt presentation, and formulating the central questions for students: *What represents the allotropes of carbon? Do you know about other famous allotropes in the nature?* One by one, there were presented and discussed: (i) *diamond*

- students being asked to solve the first task: *"Build your own diamond model using equal length sticks and modeling clay. You can use the modeling clay to symbolize carbon atoms and the sticks to symbolize the bonds in between.";*

(ii) *graphite* – students being asked to solve the second task: *"Build your own graphite model, using equal length sticks and modeling clay. You can use the modeling clay to symbolize carbon atoms and the sticks to symbolize the bonds in between.";* (iii) *buckyball* – students being asked to solve the third task: *"Build your own buckyball model, using a prototype printed on the special cardboard, prepared for you by the teacher. Simultaneously, you are invited to watch and notice another method for building a buckyball model,* illustrated in the *NTSE Virtual Lab – Making Origami Buckyballs."* At the same time, students are asked to explain the nano dimensions of the allotropes of carbon, analyz- ing the presented evidences. Finally the students concluded the most important aspects, but they were also assessed, being requested to complete a written test.

The second case study – designed for upper secondary education (9th form) – introduced the topic of *Nano- biomimicry*, a concept which combine *Nanotechnology* with *Biomimetics.* In fact, *Nanobiomimicry* is seen as the bio- logical imitation of nano and macro scale structures and processes (http://www.targethealth.com/Pages/Publications/ ONTARGET/2013/09082013.htm#3). During the activity, students discovered things that researchers in nanotechnology had learned from Mother Nature, using a strategy represented by the format of exchanging of ideas and arguments, with the view to assume the best explanations related to the importance of *Nanoscience* and *Nanotechnology* in the actual world. The analyzed examples were: (i) lotus effect; (ii) biomorphic mineralization; (iii) biologically inspired engineering; (iv)nanowires, nanotubes and quantum dots; (v) display technology; (vi) structural coloration; (vii) flock of sheep; (viii) biomimetic crystallization and structural analysis; (ix) biomineralized tissues; (x) inorganic-polymeric complex architectures; (xi) template directed synthesis; (xii) porous scaffolds for regenerative medicine; (xiii) burr à velcro; (xiv) bug à water collection; (xv) sharkskin à swimsuit.

In the beginning of the lesson activity, the concepts of *Nanotechnology* and *Nanobiomimicry* are introduced, the class being divided into groups of students, each student playing a specific role (physicist, doctor, biologist and chemist). Each group has to decide on the advisability of applying of nanotechnology in the actual society context, by answering to central questions: *What is Nanotechnology? What is Nanobiomimicry? How those areas influence our life and what could be the main application?* With the view to offer the best answer, the groups must undertake a research (documentation), analyze the evidences, formulate the arguments and present the conclusions. Resources from *Virtual Lab (Understanding Nanoscale* and *Lotus Effect)* are proposed to be consulted, as well as some *Nano Repository* objects.

For finalizing the didactic process, sets of questions were proposed. The students from each group must express their personal opinions, answering to the following specific questions:

- Which are the consequences of using nanotechnology?
- Which were the most powerful pros arguments?
- Which were the most powerful cons arguments?
- Why Nanotechnology is important?
- Have you changed your opinion after the discussions? Why?
- Have you learned anything new from this lesson?
- What you have learned (specifically) from your colleagues?
- What would you like to learn more?
- From where did you get the information?
- Was your opinion adopted by the group?
- Which were, however, the areas of consensus in your group?

Figure 1 illustrates students' answers to the question: "Why do you consider that Nanotechnology is important?" As it can be observed, most of the students are aware that this is an area which causes a huge interest for the actual research (actual world). But there is also a slight perception between the category of students when they associate Nano area with human life / nature and the continuous changing of the environment.

Figure 2 shows the students' understanding related to the possible consequences of using Nanotechnology in our daily life. In this case, there is an overwhelming feedback saying that the introducing of Nanotechnology on a large scale is beneficial. However, it was recorded an important percentage of answers (just from upper secondary students) which expressed that Nanotechnology can have a harmful impact in our life. At the same time, there were students who said that there are no consequences in this sense.

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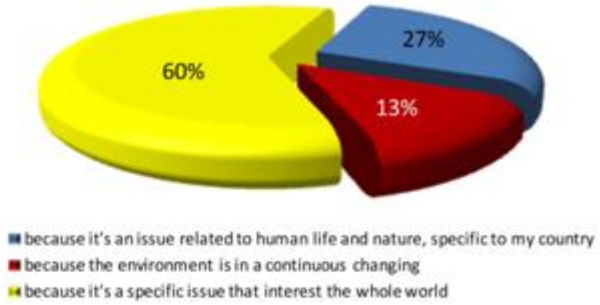
<tr><td>

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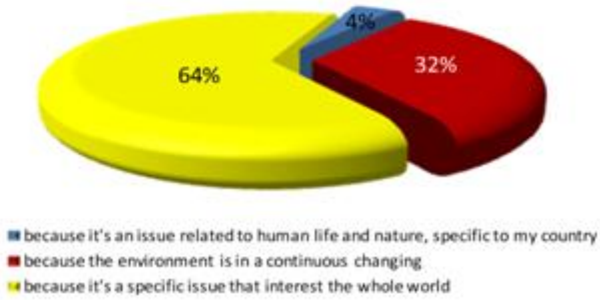
(a) Lower secondary Students</td><td>

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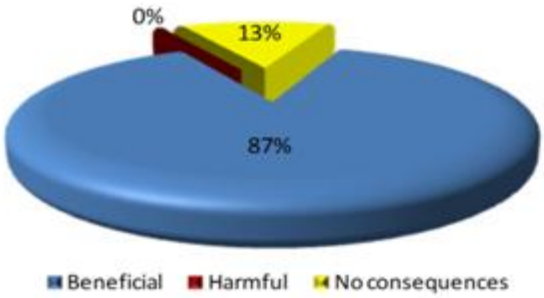
(b) Upper secondary students</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 1. Students' answers to the question: "Why do you consider that Nanotechnology is important?"</td><td></td></tr>
<tr><td>

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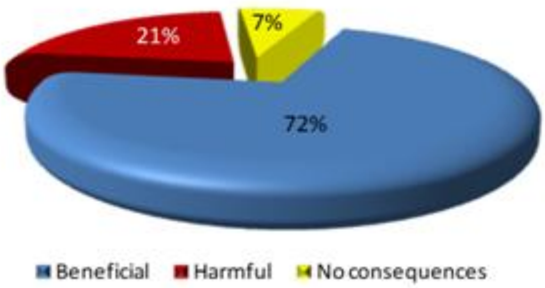
(a) Lower secondary Students</td><td>

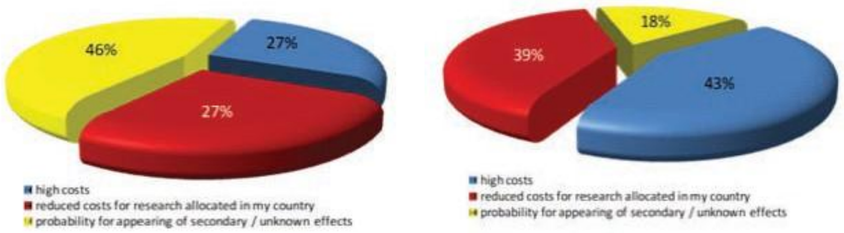
*
(b) Upper secondary students</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 2. Students' appreciations related to the possible consequences of introducing Nanotechnology in our life</td><td></td></tr>
</table>

Figures 3 and 4 illustrate the students' pros and cons arguments related to developing and applying of Nanotechnology in some specific contexts. The results can be analyzed from different perspectives, but it is important to mention that students are aware that Nanotechnology has important strong potential for improving the quality of life and curing incurable diseases. On the other hands, the students know that it is a high-consuming resources area and there are not so much money allocated in Romania.

Figure 3. Students' pros-arguments related to developing and applying of Nanotechnology

(a) Lower secondary Students (b) Upper secondary students

Figure 4. Students' cons-arguments related to the developing and applying of Nanotechnology



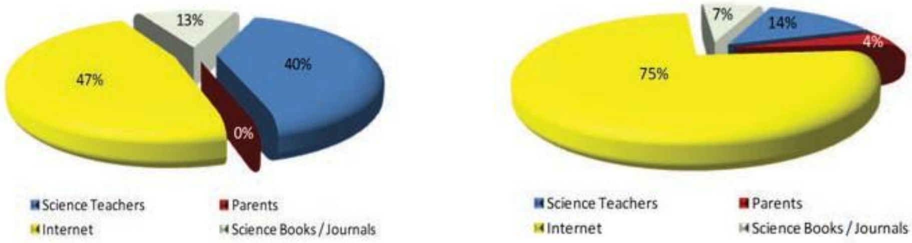
(a) Lower secondary Students (b) Upper secondary students

Figure 5 illustrates the students' answers related to how their opinions about *Nanotechnology* had been changed after the group / class discussions. Here, it can be noted that most of the lower secondary students were influenced by the group / class discussions (60%). On the other hand, 79% of the upper secondary students expressed that the discussions did not change their initial ideas related to *Nanotechnology*.

Figure 5. Students' answers to the question: "Is your own opinion changed after the group/class discussion?"

One of the most interesting questions was related to the sources of information accessed by the students for extending their knowledge about *Nanoscience* and *Nanotechnology*. In this respect, Figure 6 shows the important role played by Internet, as a valuable source of information. It is also the case of *Nano-Technology Science Education – NTSE* project, which provides its resources (including the *Virtual Lab*) in a dedicated space on Internet. But, it is clear that Science teachers need to be more involved and active at the moment when they make connections between real- life phenomena and *Nanoscience,* or when presenting physical or chemical processes which can be explained using specific *Nanotechnology* concepts. At the same time, teachers have to give more importance to the Science literature and ask the students to take more into account the articles published in scientific books or journals.

In many situations, teachers use case studies like teaching tools to show and evidence the application of a theory or a concept to real situations. In addition, they exploit case studies as specific didactic methodology which has the main role to develop the students' knowledge.
Figure 6. Students' feedback related to the question: "What are the main sources for getting information related to Nanoscience and Nanotechnology"?



(a) Lower secondary Students (b) Upper secondary students

In the situation of both presented case studies, ICT represented a real support for understanding *Nanosci-ence* and *Nanotechnology* issues. In fact, learning *Nanoscience* and *Nanotechnology* by the use of ICT (through the designed resources included in the *Virtual Lab*), could be a feasible way for motivating the students, due to the wide possibilities for presenting related Nano concepts in multimedia formats (Gorghiu, & Gorghiu, 2012). On the other hand, at the student's level, the impact of such activities was major, maximizing the involvement in the proposed activities and multiplying the understanding of the real world. More, practical activities (like experimenting and modeling) made together with the colleagues inside the working group, offered an important social impact.
Concerning the implementations at the university level, there were three case-studies developed by the Romanian partner at the level of bachelor, master and PhD students.
The first case study entitled "Nanoparticles / Nanomaterials – Small things behind a stunning world" was realized by Teaching Assistant Radu Lucian Olteanu after the activity organized with bachelor students / prospective teachers with purpose to provide them a basically and advanced approach on to the NANO area. The students developed an essay which contained a virtual or real experiment that can be applied in laboratory. Having in view they were students from Science area (Physics-Chemistry) and moreover prospective teaches, they had to take care also to didactical and pedagogical aspects. Some of the selected information / examples made available to the students were from the NTSE Virtual Lab (teaching materials) and from NTSE database (Repository) under L Education (General) and Q Science (General) sections.
The second case study, entitled "Nanofibres" realized by Associate Professors Crinela Dumitrescu and Laura Gorghiu was based on the activity dedicated to familiarize master students / prospective teachers of science with important concepts related to nanofibers and their use in everyday life and the methodology followed during the implementation it was mainly the same as in the first implementation to the bachelor students. The activity designed for the *Chemistry master students (second year),* sought to develop the knowledge, skills and attitudes of students involved, so that they can participate effectively in discussions on topical issues. At the same time, it stressed the direct exchanges of ideas and experience, laboratory work, to take a clearer picture of the investigative approach in action.
For finalizing the didactic process, both bachelor students and master students were invited to fill in a questionnaire, in order to design a graphical feedback after processing their answers. "Questionnaire for master students/ prospective science teachers" aimed at assessing and collecting information and suggestions on teaching effective- ness, content and usability of educational materials dedicated to teaching / learning Nanotechnologies created in the project Nano-Tech Science Education and uploaded in the NTSE Virtual Lab. The students had to express their personal opinions, answering to the following specific issues:

– Pedagogical approaches:
- General pedagogical criteria:
- The clarity of stated educational objectives and the expected results;
- If the teaching materials meet the stated educational purpose;
- The clarity of the learning objectives;
- Tasks are clearly described;
- If the activities are adapted to the target group.
- Pedagogical requirements focused on teacher:

> To set their own learning goals;
> To search and explore information;
> To collect and retrieve information;
> Communicate with students;
> To seek and receive support from experts in Nanotechnologies.

– Effectiveness of the content:

✓ Information:

> Information included are detailed and comprehensive;
> Information included is relevant to the educational objectives set;
> Information included are appropriate for the target group;
> Information included helping to enrich the curriculum content;
> Included information are related to relevant online resources;
> Information included not contain labels or stereotypes political invoice / cultural / social / racial humiliation;
> Information included are updated with current topics in the field of nanotechnology
> Information sources are detailed.

✓ Structure:

> Information included are well structured and organized;
> Included texts are well structured;
Labels are suitable and representative sections for the information;
> Online resources related with information are relevant;

✓ Presentation / Design:

> Images and sounds included are properly referenced;
> The texts are readable in terms of color, size, font type, arrangement and visual effects;
> Graphics, images and videos included are well presented in terms of resolution, color and size;
> Graphics, images, sound and video resources used are appropriate for the purpose;
> Using images, videos and audio facilitates understanding;

✓ Accuracy:

> Links included in the proposed resources are appropriate and functional;
> The language used is correct syntactically and grammatically;
> Do you think there is a step that was omitted in the description of instructions or training materials?;

✓ Designed tasks:

> The information provided was relevant and motivating for understanding topic task;
> Do you consider appropriate / interesting the introduction of laboratory work related to nanomaterials / nanotechnologies?;
> You find it useful to acquire additional knowledge about nanomaterials / nanotechnologies?

The comparative results obtained at the level of bachelor and master students are presented in the following figures. First of all, concerning the activity as a whole, the following ideas could be emphasized from the expressed feedback of both target groups:

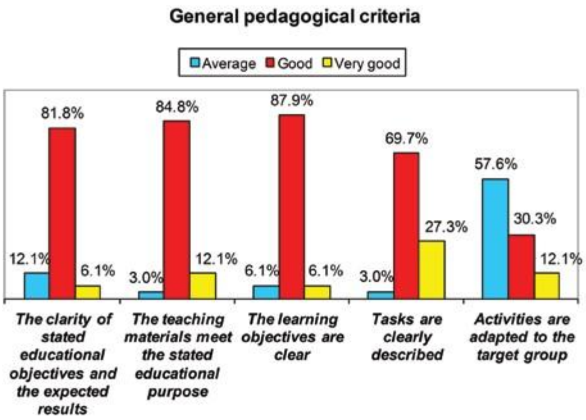
- real and actual issues have been discussed;
- opportunity to work in groups and know better the colleagues;
- possibility to express own opinion on certain issues;
- possibility to communicate without fear with the colleagues, and also with the teacher;
- proper frame to argument the own opinions, as well as listening patiently to others;

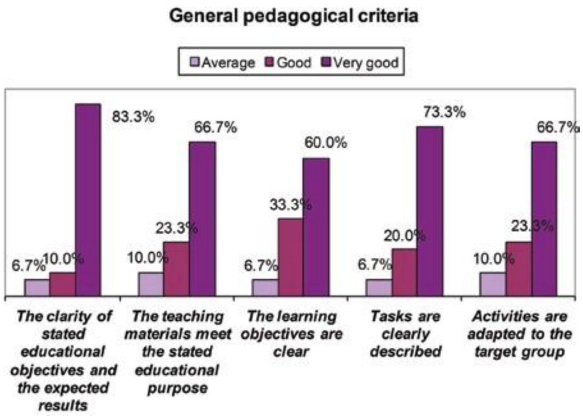
- opportunity to compile documents and find out things that otherwise are not so easy to know.

All students declared that they learn something new, interesting and actual during the activity. They were motivated and very interested to the presented / discussed subjects due to the fact that those topics aren't greatly deepened during university curricula.

– Pedagogical approaches:

✓ General pedagogical criteria:





✓
✓

(a) Bachelor students / prospective teachers
(b) Master students / prospective teachers

> The clarity of stated educational objectives and the expected results;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	12,1%	81,8%	6,1%
Master students / Prospective teachers	6,7%	10,0%	83,3%

> If the teaching materials meet the stated educational purpose;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	84,4%	12,1%
Master students / Prospective teachers	10,0%	23,3%	66,7%

> If the teaching materials meet the stated educational purpose;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	84,4%	12,1%
Master students / Prospective teachers	10,0%	23,3%	66,7%

> The clarity of the learning objectives;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	6,1%	87,9%	6,1%
Master students / Prospective teachers	6,7%	33,3%	60,0%

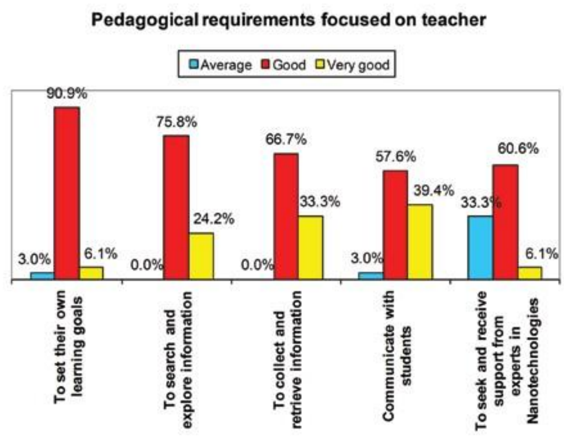
> Tasks are clearly described;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	69,87%	27,3%
Master students / Prospective teachers	6,7%	20,0%	73,3%

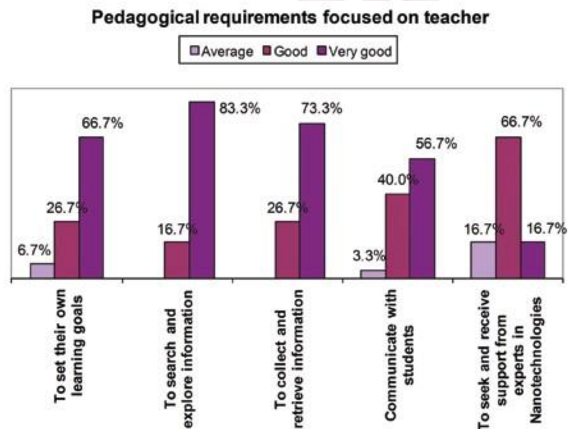
> If the activities are adapted to the target group.

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	57,6%	30,3%	12,1%
Master students / Prospective teachers	10,0%	23,3%	66,7%

✓ Pedagogical requirements focused on teacher:



(a) University students / prospective teachers



(b) Master students / prospective

> To set their own learning goals;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	90,9%	6,1%
Master students / Prospective teachers	6,7%	26,7%	66,7%

> To search and explore information;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	0,0%	75,8%	24,2%
Master students / Prospective teachers	0,0%	16,7%	83,3%

> To collect and retrieve information;

Students' grade	**Assessment grades**		
	Average	Good	Very good
Bachelor students / Prospective teachers	0,0%	66,7%	33,3%
Master students / Prospective teachers	0,0%	26,7%	73,3%

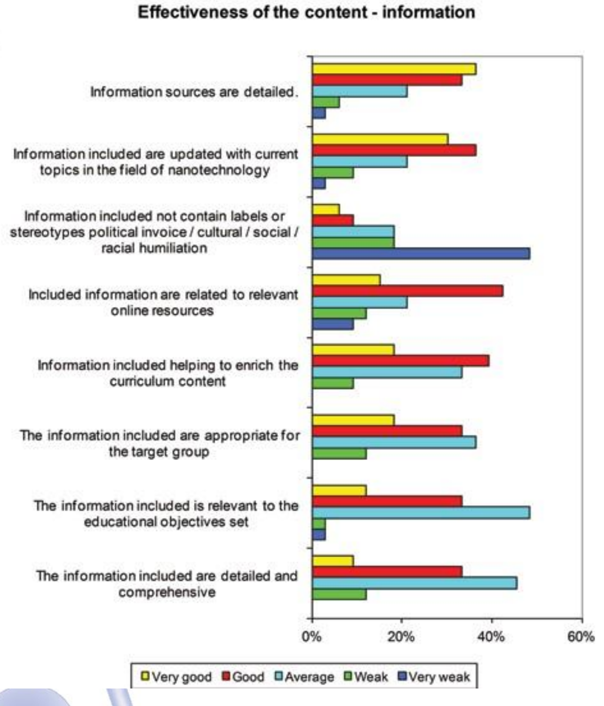
> Communicate with students;

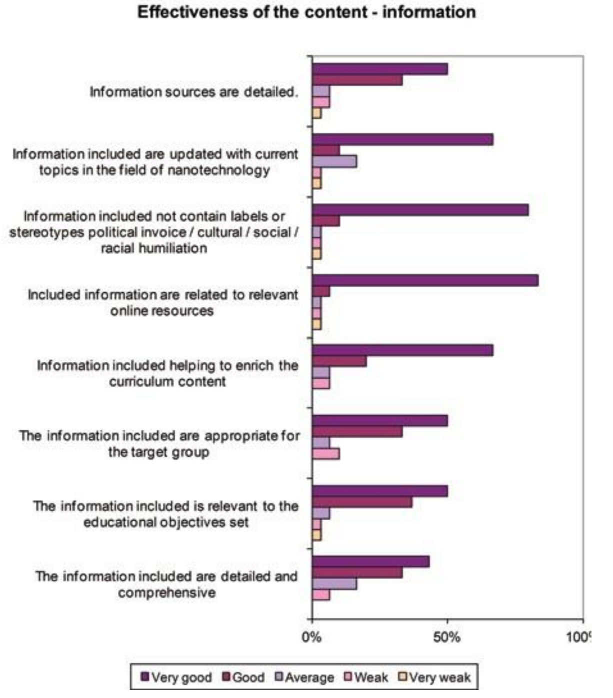
Students' grade	Assessment grades		
	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	57,6%	39,4%
Master students / Prospective teachers	3,3%	40,0%	56,7%

> To seek and receive support from experts in Nanotechnologies.

Students' grade	Assessment grades		
	Average	Good	Very good
Bachelor students / Prospective teachers	33,3%	60,6%	6,1%
Master students / Prospective teachers	16,7%	66,7%	16,7%

-Effectiveness of the content: Information:





(a) University students / prospective teachers teachers

(b) Master students / prospective

> Information included are detailed and comprehensive;

Students' grade	Assessment grades				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	0,0%	12,1%	45,5%	33,3%	9,1%
Master students / Prospective teachers	0,0%	6,7%	16,7%	33,3%	43,3%

> Information included is relevant to the educational objectives set;

Students' grade	Assessment grades				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	3,0%	48,5%	33,3%	12,1%
Master students / Prospective teachers	3,3%	3,3%	6,7%	36,7%	50,0%

>Information included are appropriate for the target group;

Students' grade	Assessment grades				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	0,0%	12,1%	36,4%	33,3%	18,2%
Master students / Prospective teachers	0,0%	10,0%	6,7%	36,3%	50,0%

> Information included helping to enrich the curriculum content;

Students' grade	Assessment grades				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	0,0%	9,1%	33,3%	39,4%	18,2%
Master students / Prospective teachers	0,0%	6,7%	6,7%	20,0%	66,7%

> Included informations are related to relevant online resources;

Students' grade	Assessment grades				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	9,1%	12,1%	21,1%	42,4%	15,2%
Master students / Prospective teachers	3,3%	3,3%	3,3%	6,7%	83,3%

> Information included not contain labels or stereotypes political invoice/ cultural/ social/ racial humiliation;

Students' grade	**Assessment grades**				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	48,5%	18,2%	18,2%	9,1%	6,1%
Master students / Prospective teachers	3,3%	3,3%	3,3%	10,0%	80,0%

> Information included are updated with current topics in the field of nanotechnology;

Students' grade	**Assessment grades**				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	9,1%	21,2%	36,4%	30,3%
Master students / Prospective teachers	3,3%	3,3%	16,7%	10,0%	66,7%

>Information sources are detailed;

Students' grade	**Assessment grades**				
	Very weak	Weak	Average	Good	Very good
Bachelor students / Prospective teachers	3,0%	6,1%	21,2%	33,3%	36,4%
Master students / Prospective teachers	3,3%	6,7%	6,7%	33,3%	50,0%

Important: the last part of the activity becomes very important, due to the fact that it represents a “debriefing” of everything the student has learned and lived during the whole process. The proposed questions dedicated to students substantiate in fact, the activity objectives.

Comparing the obtained results it can be observed that master students are more positive about the educational materials and features offered by the NTSE Virtual Lab than the bachelor students. This can be explained by the fact that after some implementations developed in each country, based on the feedback of the in-service and prospective teachers involved in the implementation stage, the partnership decided to improve the materials and making them more inquiry based learning. If we take into consideration that the activity developed with master students took place after the new educational materials were uploaded into the Virtual Lab, it can be emphasized an improvement of all the materials made available in the Virtual Lab. Based on these results, the Romanian partner has in view – in the context of the project exploitation – the development of new implementations of the educational materials prepared in the frame of the NTSE project for other classes of students.
The third case study made by PhD Student Andrei Chilian under the support of Professor Jipa Silviu was entitled “Deposition of TiO2 Nanoparticles on Optoelectronic Materials for Achieving Dye-Sensitized Solar Cells”. The main reason of the activity developed at the PhD student level was to attract more PhD students to study NANO area. PhD students had to realize several laboratory

experiments with nanoparticles. This activity was performed for PhD students involved in studying Engineering Sciences (1st and 2nd Year of study), because for developing the proposed experiments is requiring physics and chemistry knowledge.

Following this activity, the PhD students got several important capabilities:

- To work in groups;
- To interpret the obtained data;
- To improve their working mode;
- To implement new methods of working;
- Study the impact of various factors on the working method;
- To achieve good and real results;
- To learn new working methods;
- To learn to work with various tools of analysis;
- To make analysis of the surface of the materials;
- To interpret the SEM analysis, XRD (X-ray diffraction).

In the NANO area, PhD students learned more about: importance of nanoparticles in DSSC; how to obtain TiO2 nanoparticles; electronic transitions at the interface of TiO2 nanoparticles and dye; the advantages of using TiO2 nanoparticles compared with the use of particles of different sizes; the dyes with best photoelectric properties; electrolytes used for obtaining DSSC; the electrodes used for deposition of TiO2 nanoparticles and using of other nanoparticles types in DSSC.

After retrieving the information and after the practical activities, PhD students are able:

- to make a report with the obtained results;
- to put into practice the knowledge about nanoparticles;
- to identify how nanoparticle size influences the efficiency of DSSC;
- to examine the advantages and disadvantages of this technology based on nanoparticles;
- to develop individual knowledge about NANO;
- to produce a scientific paper and present it at national or international conferences;
- to improve deposition techniques TiO2 nanoparticles on optoelectronic materials.

Concerning the group management and sequence of events, all the activities started from the idea that TiO2 nanoparticles are of high importance regarding their use as n-type element in dye sensitized solar cells (DSSC). Now, it is manifested an increased interest for technologies related to this type of photovoltaic cells. Therefore, the study of the properties and their deposition techniques require improvements.

Before starting the practical work, PhD students had studied the theoretical aspects related to methods of TiO2 nanoparticles deposition. Also, they received materials (scientific articles and books related to the deposition techniques).

To expand the horizon of knowledge in NANO, PhD students started to consult materials of *NTSE Virtual Lab Project* (http://vlab.ntse-nanotech.eu/NanoVirtualLab/) – especially dedicated to nanoparticles (see the video-clip *"Iron Nanoparticles"* from *Experiments Room*), and *NTSE Repository* (http://ntse.ssai.valahia.ro/), starting with the consultation of the article: *"The current state of public understanding of nanotechnology",* authors: Anna M. Waldron, Douglas Spencer and Carl A. Batt – uploaded in the NTSE Repository, at URI: http://ntse.ssai.valahia.ro/id/eprint/20, and of book specific paragraphs: Kenneth Kuno – *"Introduction to Nanoscience and Nanotechnology: A Workbook",* uploaded in the NTSE Repository, at URI: http://ntse.ssai.valahia.ro/id/eprint/35.

After the documentation stage, with the view to facilitate the assimilation of the Nano knowledge related to the studied Nano theme (*Deposition of TiO2 nanoparticles on optoelectronic materials*), the work has been divided into several sections:

Section	Location	Activity

Section 1	Chemistry Lab (60 – 90 min)	The instructor does an introduction in the field of dye-sensitized solar cells (DSSC) and explains the importance of TiO_2 nanoparticles in them. PhD students are divided into groups (2 groups of 4 people) and receive work instructions for realization of experiments.
Section 2	Outside Lab	Consultation of materials and study of nanoparticle TiO_2 deposition methods
Section 3	Chemistry Lab (60 – 120 min)	The first group of PhD students begins the TiO_2 nanoparticles deposition by liquid phase deposition (LPD) (48 h). In parallel, the second group begins experiment of TiO_2 nanowires deposition by hydro-thermal method (24 h).
Section 4	Outside Lab	Individual study related to deposit methods.
Section 5	Chemistry Lab (45 – 60 min)	Meeting with the second group after 24 h and finalization of TiO_2 nanowires deposition experiment by hydrothermal method and removing of FTO plates from chemical bath.
Section 6	Chemistry Lab (45 – 60 min)	Meeting with the first group after 48 h and finalization of TiO_2 nanoparticles submis-sion experiment by liquid phase deposition (LPD).
Section 7	Outside Lab	PhD students study observed phenomena in experimental work and seek additional material.
Section 8	Chemistry Lab (60 – 120 min)	The first group of PhD students begins the experiment of TiO_2 nanowires deposition by hydrothermal method (24 h). In parallel, the second group starts the deposition of TiO_2 nanoparticles by liquid phase deposition (LPD) (48 h).
Section 9	Chemistry Lab (45 – 60 min)	Meeting with the first group after 24 h and finalization of experiment of TiO_2 nanowires deposition by hydrothermal method and removing of FTO plates from chemical bath.
Section 10	Chemistry Lab (45 – 60 min)	Meeting with the second group after 48 h and finalization of TiO_2 nanoparticles depo-sition experiment by liquid phase deposition (LPD).
Section 11	Chemistry Lab (45 – 60 min)	Evaluation and comparison of results. Presentation of research reports.

Additional references were also recommended to PhD students (e.g. the full articles can be downloaded from scientific databases.

Related to the procedural resources, the following methods and processes were used: research-based methods – experimenting, observing, data processing, analyzing, discussing, reporting. Both teams/groups and individual work was performed as form of organization. Like material resources and spaces, there were used instruments, reagents and utilities of Electrochemistry Laboratory, PCs, Internet access, video-projector, flipcharts etc.

For finalization of activity, PhD students had to express their personal opinions related to the experimental work, answering to a questionnaire with 20 questions that comprised the following sections: quality of expert' teaching; NANO activity; deposition method; method of deposition of TiO2 nanoparticles by liquid phase deposition (LPD); method of submission of TiO2 nanoparticles by hydrothermal method; evaluation of the experimental activity.

The impact on PhD students/Researchers at the end of activity emphasized the following aspects:

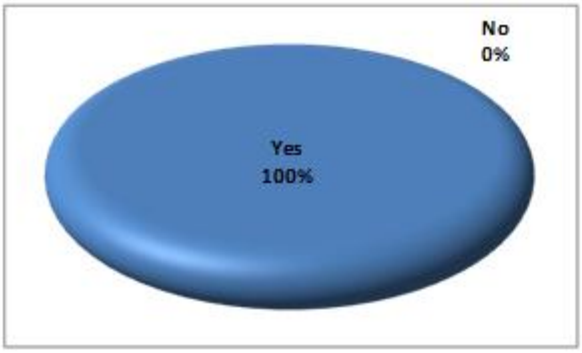
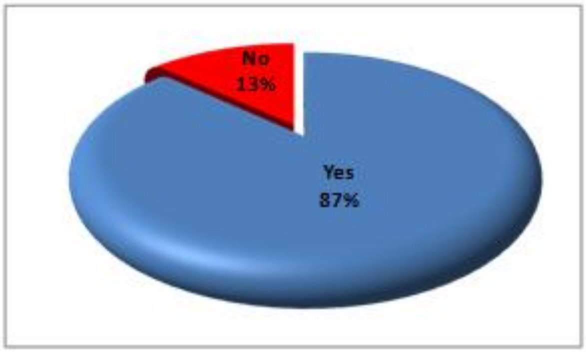
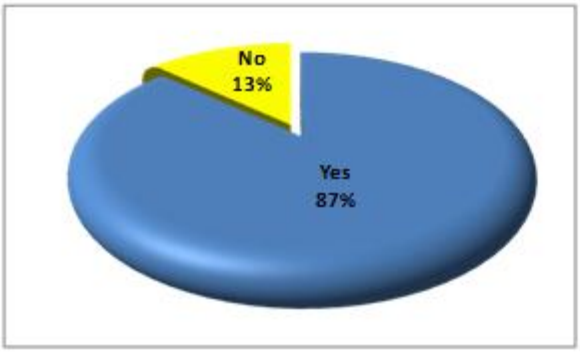
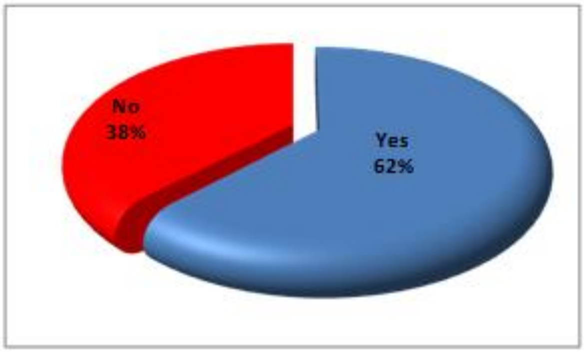
- Improvement of techniques for experimental work;
- Using theoretical concepts in solving practical problems;
- Better understanding and interpretation of the observed phenomena;

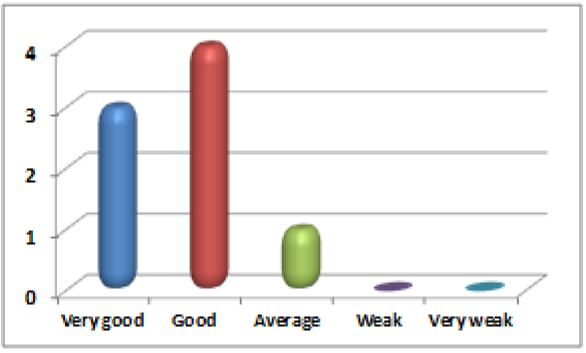
Identification of the nanoparticles role in different areas.

The following appreciations could be emphasized based on the expressed feedback of PhD students:

- Advantages of team work;
- Possibility of implementation / improvement of experimental techniques;
- Methods of deposition (advantages / disadvantages) have been discussed;
- Opportunity to consult scientific articles related to nanotechnologies and nanomaterials;
- Possibility of learning of something new.

Below are some graphical outputs of PhD students' feedback:

 *	 *
Has the instructor presented clearly the study materials?	Have you had enough materials for study?
 *	 *
Were there any doubts during the experimental study of materials, in the related activity?	Is the performed experimental work useful for the chosen research topic?



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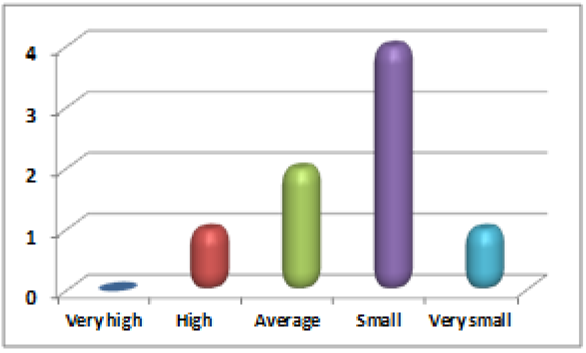
What is the degree of novelty for you of this experimental work?



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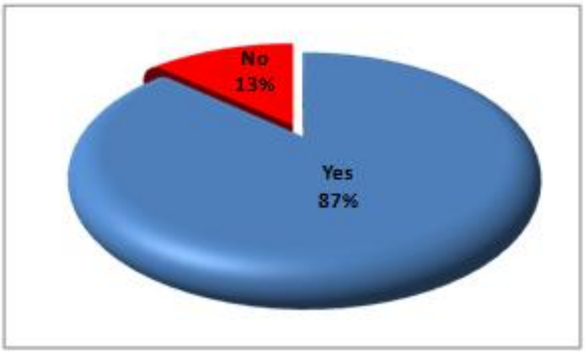
Hardness of tasks for completion of work.



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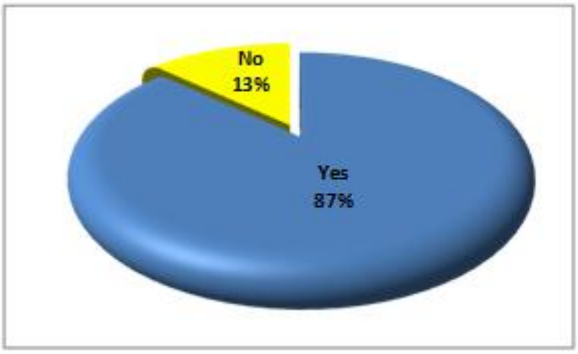
Would you also like to participate in such activities?



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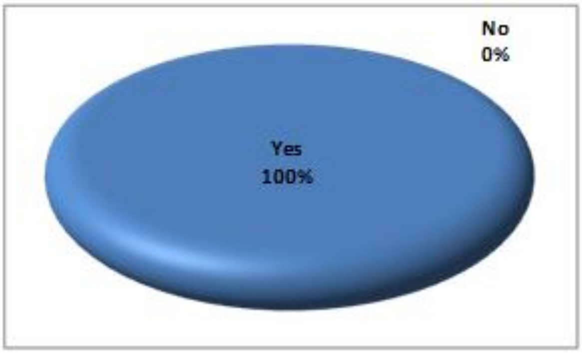
Have you changed your consideration about the importance of the NANO after carrying out this activity?



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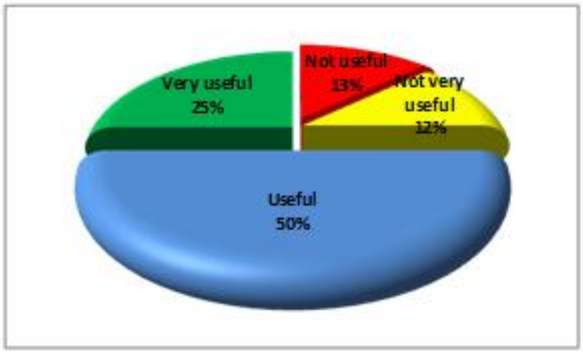
Will you study in the near future NANO-topics?



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How useful is for your this experimental work?

CASE-STUDIES SUMMARY: BULGARIA

The case studies in Bulgaria were implemented by 5 teachers with 165 students from 8th grade (lower sec- ondary school level) and from, 10th, 11th and 12th grades (upper secondary school level) in 4 different schools. The topics chosen by the teachers are:

1. “Nanoscale and Nanotechnology”
2. “Allotropes of carbon”
3. “Lotus effect”

Two of the teachers – Mrs. Evelina Vasileva and Mrs. Irina Kostadinova teach “Biology & Health education”; Mrs Rositsa Sotirova is a teacher in “Chemistry & Ecology”; Mrs. Kremena Dukadinova is a teacher in “Physics & Astronomy”. Mrs. Vanya Gunova teaches two subjects – “English as a foreign language” and “Biology”. Two of the schools where case studies have been carried out (the ’Akad. Emilian Stanev’ Secondary school and the Second English Language High-School) work with a curriculum with intensive foreign language learning in English. This cur- riculum provides opportunities for “content and language integrated learning” (CLIL) where subject material is thought in a foreign language. The availability of the resources in English in the NTSE Virtual Lab allowed implementation of lessons in English.

For her case study **Mrs. Evelina Vassileva** chose the **topic “Nanoscale and Nanotechnology”** and pre- sented it in two different schools to students from 8th grade (in the National Professional High-school for Fine Mechan- ics and Optics “Michail Lomonosov”) and, respectively, from 10th grade (in the 7th High-school in Sofia). The lesson with duration of 90 min. is based on the use of the NTSE Virtual Lab resources on “Understanding Nanoscale”. It provides the opportunity to explore and understand the metric system, nanoscale, properties of nanoscale particles and what nanotechnology deals with. Students have to develop the ability to convert ordinary measurement scales into nano and visualize the nano scale. For the implementation with the 8th graders the lesson was adapted in accordance to their level of scientific knowledge. The lessons with both groups were implemented in Bulgarian language.

They are involved in the subject by watching videos and presentations about nanoscale: “Nanotechnology”
at http://www.youtube.com/watch?v=OKXwdG-Kk2Q, “The powers of ten” http://vlab.ntse-nanotech.eu/NanoVirtualLab/ experimentroom/908f4cedc98349d0b57e781ae3ea29c4, The scale of The Universe: http://htwins.net/scale/, “A journey to the nanoworld”, “A boy and his atom”.

During the lesson the students execute four main activities, described in the Students’ Guidelines (NTSE V- Lab Experiments room / Understanding nanoscale / Documents). They ask and answer the following questions about the text: *What is nanotechnology?, What is scale?, What is the largest scale shown in the video?, What is the smallest scale shown in the video?, How do you feel about travelling this long distances in empty space shown in the video?* They discuss the importance of nanotechnologies – their application in everyday life, as well as the beneficial or detrimental to health of the people in the future. They measure the objects in couples and convert the measurements into nanometer. They compare the sizes of different object: red blood cells and single hair; bacteria and virus; single water molecule and single gold atom; water molecules and

Buckyball; cell, cell nucleus and carbon nanotube. Finally, they measure, calculate and compare the sizes of the figures they build with sugar cubes.

The students were mostly interested in the examples of application of nanotechnologies in the production
of tissues, prostheses, alloys, etc. They faced difficulties in converting decimals into exponential units and vice versa. They also found it difficult to calculate volume and surface area of the geometrical shapes so only a small group of students tried to solve the problem.

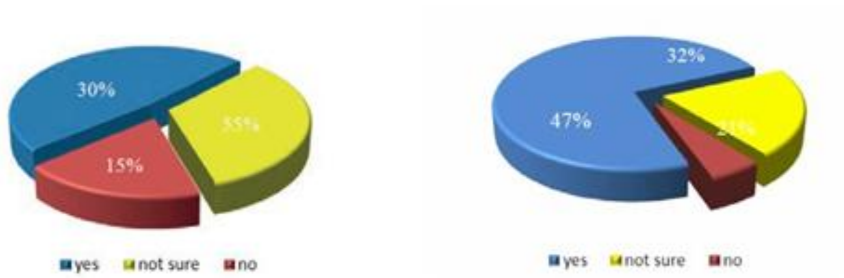
At the end of the lesson, the students fill the standard self-evaluation questionnaire prepared as part of the set of NTSE V-Lab materials for this lesson. The answers of the students are presented below as diagrams in Figures 1–8. The parallel presentation of the data for the two age groups allows comparison of the level of understanding of the lesson's topic for the students from the lower secondary and upper secondary school level.

Lower secondary students *Lower secondary students*

Figure1. Answers to the statement *"I can give an example of an object with nm scale out of concepts I have learnt"* for both lower- and upper secondary students.

Lower secondary students *Lower secondary students*

Figure 2. Answers to the statement *"I can differentiate Nanotechnological applications from the applications of conventional technology"*



Lower secondary students *Lower secondary students*

Figure 3. Answers to the statement *"I can comprehend that as the particle size changes, the physical properties change"*

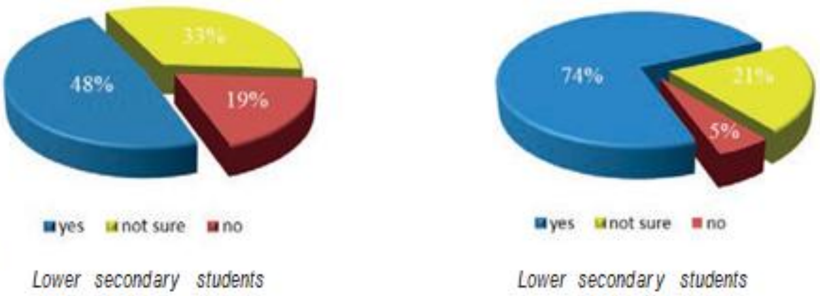


Figure 4. Answers to the statement *"I can explain why physical properties differ in granulated sugar and powdered sugar"*

Figure 5. Answers to the statement *"I can define nanoparticles according to their sizes"*

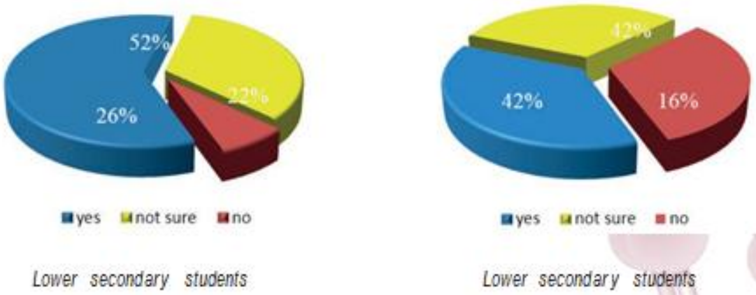


Figure 6. Answers to the statement *"When the particle size decreases to nano I can explain why the material may gain new physical properties."*

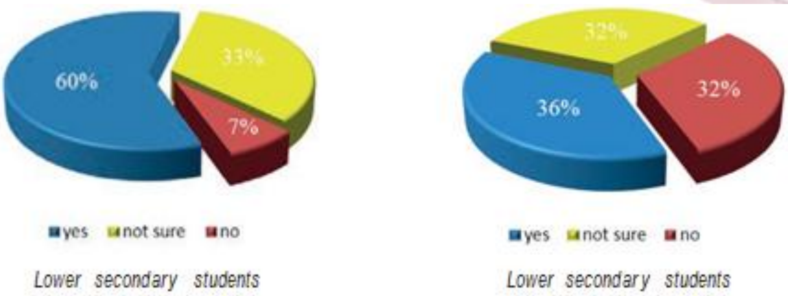
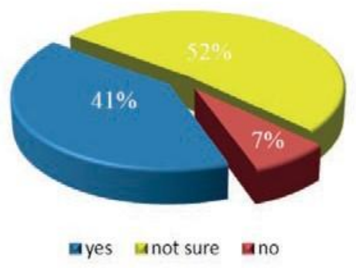
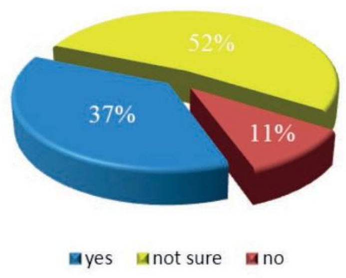


Figure 7. Pros and cons of the question *"I grasp that by applying Nanotechnology, actually we imitate the nature's technology."*



Lower secondary students



Lower secondary students

Figure 8. Answers to the statement *"I can give some examples of applications that show the large surface area makes some nanoparticles rapidly soluble in liquids"*

The topic "Allotropes of carbon" was presented in two different schools by two teachers – Mrs. Vanya Gunova in 'Akad. Emilian Stanev' Secondary school in Sofia and Mrs. Rositsa Sotirova in the Second English Language High-School in Sofia. The lesson includes scientific information for amorphous carbon, diamond, graphite, fullerenes and carbon nanotubes. During the lesson students learn notions as allotropes and allotropes of carbon; covalent bond; crystal structure of allotropes of carbon; structure of carbon nanotubes and buckyball (fullerenes); application areas of carbon allotropes etc. Both lessons utilize the resources of the NTSE Virtual Lab Experiments room – topic "Carbon Nanotubes".

The lesson implemented by **Mrs. Vanya Gunova** in "Akad. Emilian Stanev" Secondary school was aimed to help students visualize carbon nanotubes (hereinafter CNTs) which they cannot see by naked eye and to raise students' interest in both CNTs and nanotechnology. Students learn about different types of nanotubes, the production methods and a variety of application areas. The lesson was implemented in English and allowed mastering of scientific vocabulary in a foreign language.

Class preparations include designing the room to watch the experiment videos from the NTSE V-Lab and pre- paring a presentation (in Prezi) and the materials needed in the activities: students' guidelines, sheets of fence wire, microfiber cloth, ordinary cloth and two measurement containers with water.

During the lesson, the following activities are realized:

1. A brainstorming session attracting students' attention to the main topic.
2. The teacher asks questions preparing the students to watch the first video about spider silk explaining its properties. Then there is a discussion about the possible uses of technological replication of spider silk.
3. Students watch the video explaining the allotropes of carbon. They recognize carbon nanotubes as one of carbon allotropes and provide a definition.
4. Students watch the video explaining the production of carbon nanotubes and some of their uses.
5. The teacher shows pictures of different types of CNTs on the board and explains how to make their own CNTs' model out of the fence wire available on their desks. The teacher checks what type of nanotubes ("armchair", "zigzag" or "chiral") have been designed by the students.
6. Students are invited to read about CNTs properties from the Student's guidelines and fill in gapped sen- tences projected on the board.
7. Students watch an experiment video in the Virtual lab in order to recognize the water and oil absorption of materials made of CNTs. Then students discuss the amazing oil absorption property of CNTs and the possible applica- tion areas.

8. Students learn about other application areas of CNTs from teacher’s presentation and the next animation video, explaining how they are used in computer circuits.
9. Finally students watch a video about space elevator and discuss the importance of carbon and its al- lotropes in technology of the future.
10. Evaluation.

At the beginning of the lesson implemented by **Mrs. Rositsa Sotirova** in the Second English Language High- School, the teacher made a brief historical introduction (in the form of PowerPoint presentation) about the reasons for Nanoscience appearance. She introduced also the main notions as Nanoscale, Nanotechnology etc. and the purpose of the activity – to teach the students about the structure and applications of carbon allotropes – diamond, graphite and fullerenes. The lesson was carried out in English language and allowed mastering of scientific vocabulary in a foreign language.

After that, the students are divided in 4 different groups for modeling origami of different structures – graphite, diamond, buckyball and nanotubes.

After completing the activities students are able to understand the reason as to why allotropes of carbon exist, to make connections between the “micro” and “macro” world linked to real-life applications, to understand the difference in the physical properties due to different arrangement of atoms in a crystal and to work cooperatively in a group setting. Students enjoyed working in groups and collaborating with classmates. They learned visually and man- aged to apply the knowledge in problem-solving activities (question session for discussion).

For getting students’ feedback about the learning process and the level of difficulty of the topics was used the NTSE questionnaire for assessment of the Virtual lab implementations. The information from the questionnaires filled by the students after the lessons “Allotropes of carbon” is summarized and presented in Figures 9–18. Students answered to the questions giving feedback to what extent they agree or disagree with the statements where 1 means “Strongly disagree” and 5 means “Strongly agree”.

The “Reading before experiment” part was difficult to understand.

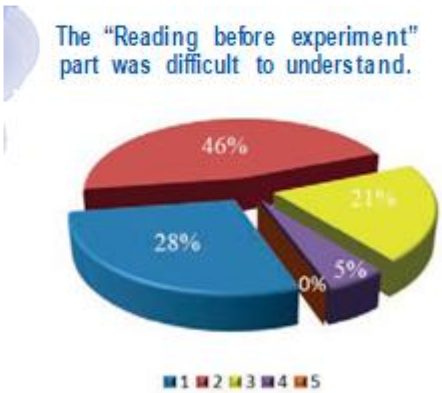


Figure 9.

The “Reading before experiment” part was very useful.

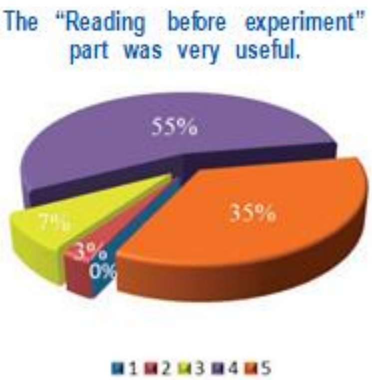


Figure 10.

Figure 11.

Figure 12.

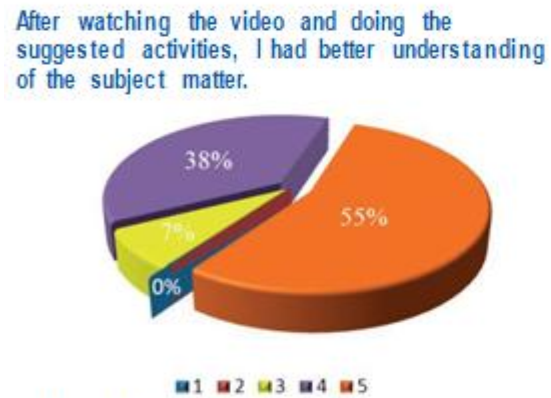


Figure 13.

Figure 14.

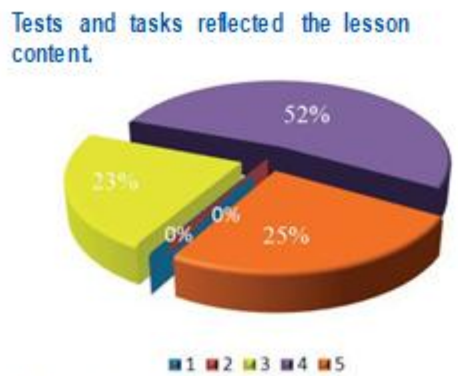


Figure 15.

Figure 16.

I learned a lot of new things in this lesson/lab.

Figure 17.

I enjoyed doing this lesson/lab.

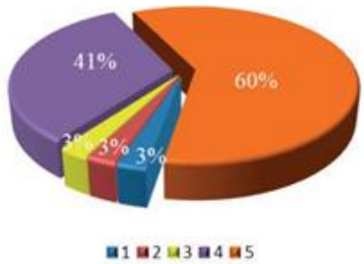


Figure 18.

The third case-study topic concerns the “Biomimicry” and especially the sub-theme “Lotus effect”. It is related with the notions as surface tension, capillary effects, wettability, hydrophobicity and hydrophilicity, molecular polarity, cohesive and adhesive forces, biomimicry. The topic was presented with the use of the resources of the NTSE irtual Lab Experiments room – topic “Lotus effect” by two teachers in two different schools – Mrs. Kremena Dukadi- nova in “Akad. Emilian Stanev” Secondary school in Sofia and Mrs. Irina Kostadinova in the Second English Language High-School in Sofia.

The main objectives of the lesson which **Mrs. Kremena Dukadinova** implemented in “Akad. Emilian Stanev” Secondary school were to demonstrate the properties of the lotus leaf and other plants, like cabbage, cauliflower, hazelbush, lettuce; to bring the observed effect of self-cleaning with the physical forces – cohesive and adhesive and their manifesting during the contact with water; to discuss about some applications of the nanotechnology based on the “lotus effect”.

During the lesson the students read the “students guide” (NTSE Virtual Lab Experiments room/ “Lotus effect”/ Documents), watched videos, video-simulation and presentation on the topic. They made experiments with dif- ferent kind of plant leaves available and discussed the observed phenomena. They made additional experiments with different surfaces and materials:

- glass plates with surface which is pure or treated with chemical (anti-fog, water repellent spray);
- paper (baking and writing),
- surfaces covered with water and oil.

Students explained the effect of the foam and detergents in the cleaning process.

At the very beginning of the lesson carried out by **Mrs. Irina Kostadinova** in the Second English Language High-School the students were informed about the main goals of project “Nano Technology Science Education” (NTSE) in the frame of which they receive the main information on the topic, summarized and available by the project site: http://www.ntse-nanotech.eu/. The lesson was implemented in English and allowed expanding of the students’ scientific vocabulary in a foreign language. During the lesson the students read the text on “Lotus Effect” from the NTSE Virtual Lab Experiments room and try to answer the following questions related to the received information:

- Why lotus is so interesting plant for scientists?
- How the lotus surface is represented on the text?
- How to explain the structure of the lotus leaf in microscopic level?
- To understand better the physical phenomenon –lotus effect.
- What we already know about water-walking insects?

After that, the demonstration of floating needle is made and scientific explanation of the surface tension is done. Other demonstrations – of capillary action of water (cohesive/adhesive forces), of soap molecules action (hydro- philic and hydrophobic side of molecule) were presented.

- What happens when water is dropped on the lotus leaf?
- What applications might have been developed by engineers inspired by Lotus effect?
- Biomimicry – imitation of the nature.

The activity is focused on three main problems:

- Understand the lotus effect watching Videos 1 and 2. Discussing the structure of the leaves and their self- cleaning and hydrophobic properties.
- Examine (with the help of optical microscope) the surface of different leaves and their properties to repel water and mud.
- Observe the action of anti-fog and water repellent spray on glass

Finally, the students filled a questionnaire for evaluation of the content and usability of educational materials and learning Nanotechnologies, created in the project „NanoTechnology Science Education" in the NTSE Virtual Lab. The information from the questionnaires is processed and presented in Figures 19–28. Students answered to the ques- tions giving feedback to what extent they agree or disagree with the statements where 1 means "Strongly disagree" and 5 means "Strongly agree".

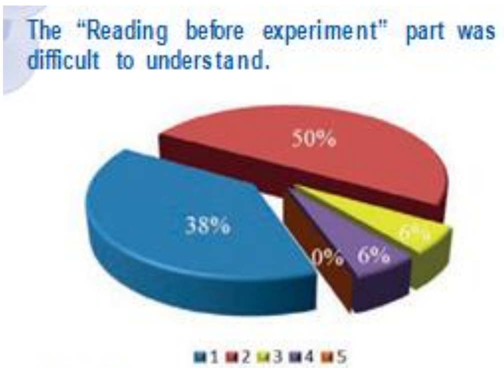


Figure 19.

Figure 20.

Figure 21.

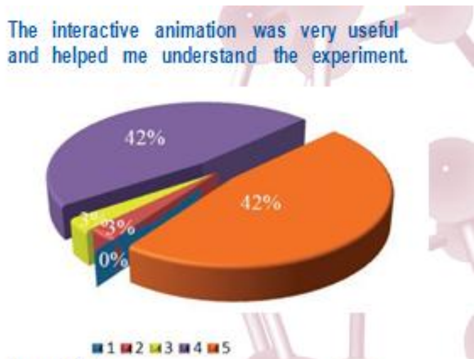
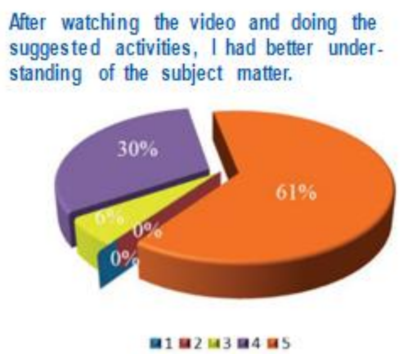


Figure 22.



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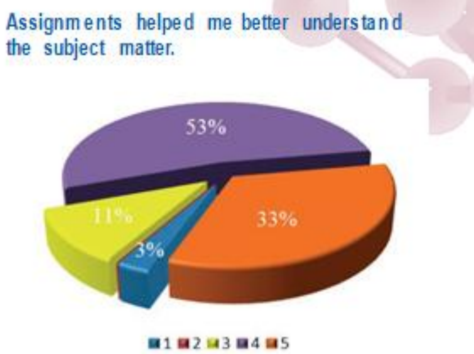

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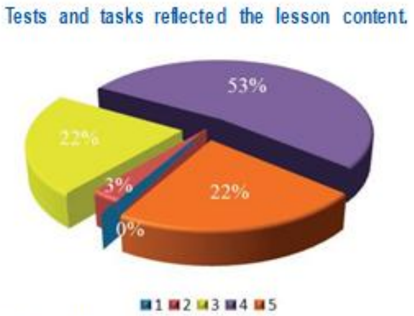

Figure 25.

Figure 26.

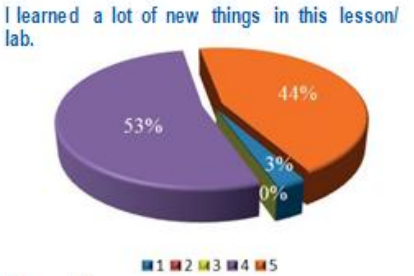

Figure 27.

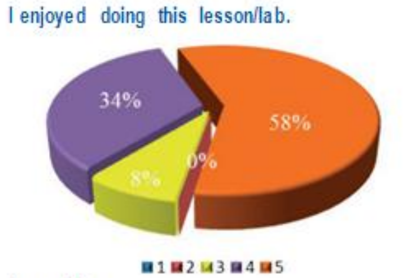

Figure 28.