



GRID Project Case Study:
“Physics on show”
I.T.I.S. Maxwell
Turin, Italy

I- Context of the school

The project has been realized thanks to the cooperation among teachers and students of two schools of the Torino district: a higher secondary school (ITIS J. C. Maxwell) and a primary school (Scuola elementare di Vinovo).

The J.C Maxwell is both a higher secondary and a technical school which offers 3 different leaving certificates with a specialisation in scientific studies, in electronics and telecommunications, as well as computer science. It is based in Nichelino, a small town near Torino, with a population approximately of 50.000 inhabitants. Nichelino, as most of suburbs at the periphery of big towns, bears everyday problems, typical of the post-industrial period, such as an high unemployment levels and many social problems, especially concerning young persons. The local public authorities in cooperation with the schools are engaged in revitalizing the social context as well as in motivating youngsters to study. This project is in line with this objective, because it aims at motivating young students (first two years of the technical course) to study science.

The “Circolo didattico di Vinovo” groups classes both from primary and pre-primary levels. Since most of pupils at primary level attend school 40 hours a week, the school organises many play and sport activities to contribute to the pupils growth from the intellectual, psychological and social-emotional point of view.

Teachers of the two schools met during a training course on physics between 1998 and 2002 and the first initiative, titled “La Scienza Amica (Friendly Science)” originated from their will of cooperation and from the suggestion of the Vinovo school’s manager. Teachers kept cooperating during the following years, dealing with various physics subjects, like gravity forces, sound and, most recently, light.

Description of the school policy

The project is part of the school development plan (POF) of both schools (secondary and primary) as it is supported at school level.

The ITIS Maxwell promotes many projects in this field of science education, aimed at increasing the students’ interests towards scientific subjects, thanks to a group of proactive science teachers. Among the initiatives realised in this school, the RADON project, which is an education project on the risks related to the exposure to radon, one of the most dangerous physical pollutants of the environment, has been already analysed by the GRID Project (see respective QE2). The “Curves representation methodology: the Bézier curves, an example of applied maths initiative” (BEZIER CURVES), realised with students of the final year of the higher secondary course specialized in science studies, has been also object of a specific case study.

The “Circolo didattico” of Vinovo pays particular attention to the cooperation with laboratories and to the initiatives promoted by the teaching staff. In particular, in recent years science teachers have studied in depth the physics teaching methodology, starting from the consideration that this subject is often overlooked in the primary school, while it would enable pupils to acquire a scientific attitude which will help them in continuing their studies.

The Physics on show initiative in the frame of the GOLD TRAIN project

The former project realized by prof. Bardi and colleagues in 2002/3 – called “La Scienza Amica” (Friendly Science) - has been recorded in the GOLD Database - the on-line database of the most interesting and innovative good practices realized within Italian schools, created by INDIRE (the National Institute for Documentation of Innovation and Pedagogical Research). Furthermore, it has been selected as best practice in the frame of the GOLD TRAIN (TRAnsferrability and INnovation) project, which is a two years period project, promoted by the Fondazione per la Scuola della Compagnia di San Paolo (Foundation for schools) and realized in cooperation with INDIRE and Gruppo CLAS, aiming at transferring and disseminating selected best practices in schools (different from those which realized them).

The GOLD TRAIN project main actions are the following:

- examination of good practices recorded in the GOLD database and those selected by the Fondazione S. Paolo by means of a competition, in order to identify 12 practices to be transferred;
- cases study on the selected best practices;
- discussion on the forum about the transferability of good practices in new schools;
- call for proposals addressed to schools interested in transferring a best practice;
- launching of the initiatives in the winner schools, in cooperation with the schools that first realized the practice. The GOLD TRAIN staff is in charge of the monitoring and the technical help.
- dissemination of the best practices transfer guidelines.

110 projects have been presented in the first call. 15% of them applied for the “La Scienza Amica” (Friendly Science) project. Actually “Scienza Amica” is under way in two schools in the south of Italy (Caserta and Palermo). Schools can also autonomously undertake the initiatives, taking advantage of the material available on-line as well as of the on-line forum and the virtual space of discussion.

Difference between the former initiative “LA SCIENZA AMICA” and the current project “PHYSICS ON SHOW”

The initiative of professor Bardi has now really changed from those realised in 2002/3. In fact LA SCIENZA AMICA - the former initiative - has been realized in a different context and situation, with more funds available and in cooperation with a group of teachers and selected students who were working on a wellknown subject, the gravity forces. In the former project the focus was mainly on the primary school pupils’ learning process. On the contrary, the current project has been realized mainly by prof. Bardi and involves 2 classes of the first lower secondary school year by working on subjects not before included in the curriculum, like optics and sound. Furthermore prof. Bardi’s work in recent years has gradually focused on secondary school students’ cognitive process, by including students not particularly brilliant in physics, trying to stimulate them and gratifying their participation and commitment in the school activities.

II- Context of the pedagogical project

Description of the whole plan

The project involves teachers and students of two levels of school - primary and higher secondary - in activities which deepen physics subjects. This case study takes into consideration in a privileged manner the work done at secondary school level, as the initiative organised by prof. Bardi is aimed at stimulating students of secondary school in studying science, by making them conceiving, planning and realizing a number of experiences to guide and assist peers and younger pupils in learning.

The point at issue is to make students of both levels discovering together the mechanic, magnetic, acoustic and optic phenomena which regulate the everyday life.

Teen-aged students are asked to play the role of tutors, in order to show to the youngest physics phenomena by means of simple and telling experiments. The primary pupils are leaded by their teachers to discover and

experience “How an object works”, whether it is a common object or a didactic object expressly created for the occasion.

The main project’s steps are:

- separate parallel training sessions for primary pupils and teachers as well as for secondary students in order to prepare them for the common activities on a chosen subject (acoustics, gravity, light...)
- organisation of learning paths in which older students lead their younger colleagues through experimental activities to discover physic phenomena in a chosen subject.

Training

The secondary school students’ training is held by the teacher and includes: conceiving, planning and creation of telling experiences in physics to be shown to primary pupils, by means of multimedia tools and hands-on activities, such as the creation of “simple didactic objects”. Also the historical point of view is taken into consideration. The training phase is aimed not only at developing in students the cognitive and communicative competencies, needed to play the role of tutors, but also at making them experiencing the “pleasure of knowledge and conveying knowledge”.

Learning paths



The pedagogical sequence is organised in a sort of “learning path” consisting of six working groups / tables each of them dealing with a different aspect related to the physics subject treated, which is illustrated by a couple of (higher secondary school) students as tutors. The primary school pupils are subdivided in groups of 7-8 pupils. Each group goes from one working group / table to the next working group / table and attends the different experiments illustrated by tutors (= higher secondary school students). At the end of the course there is foreseen a moment of sharing and confrontation, in which is carried out a kind of group evaluation of this experience.

During the school year 2005/2006 different pedagogical sequences / learning paths have been organised dealing with different subjects:

Acoustics (realised with 3rd year pupils of primary school)

- **1° table:** “how we perceive the sounds”. To illustrate by means of objects some different sounds and noises: low, high, shrill etc. The sound detector allows to see how the sound is propagated.
- **2° table:** “how the sound is propagated through solids, liquids and air”...the telephone “with wires”. What happens when a telephone rings in a bell vacuum jar?
- **3° table:** the origin of sound: the sonorous vibrations. Springs, diapason, rice grains on a drum, etc.
- **4° table:** listening and display: a drop of water falling into a bowl (basin). How to use the tool for studying sound-waves.
- **5° table:** to see sound waves by means of an oscilloscope: comparison with the oscillation produced by a 440 Hz diapason.
- **6° table:** music instruments: guitar and violin. Bottles as organ-pipes. Difference between empty and full bottles.

Gravity (realised with 4th year pupils of primary school)

- **1° table:** everything moves - experiences with the “helioplanetario”.
- **2° table:** falling into the vacuum of different sheets (crumpled up and spread out). Vacuum tube and perforated bottles.

- **3° table:** the law of universal gravitation: a model made of simple materials (i.e. small glass, string, rings, small tube or penholder) shows that “*every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them*”.
- **4° table:** every object has its own gravity field / every mass generates a gravity field. Experience with the tight elastic band. Finding the acceleration of gravity using a pendulum.
- **5° table:** overcoming the gravity. The spring-rocket: from throwing an object to travelling to space.
- **6° table:** finding the origin of our weight. The earth and moon dynamometer: a computer simulation.

Optics – (realised with 4th year pupils of primary school) - The optics learning path has been the object of the present case study – please see also the **pedagogical grid** in attachment.

The learning process

The learning methodology used to introduce the physics subjects to primary school pupils is based on a playful approach. All experiences and objects (as well as computer simulations) presented to the pupils are conceived to foster their natural playful attitude towards the reality. The game raises pupils’ curiosity and sense of discovery (How does it work? What’s inside? Why goes it like this? Etc.). By this way physics loses its abstractiveness, as a school lesson not linked with reality, and becomes a helpful tool to answer questions which really interest children. Furthermore, while children “simply play” with physics phenomena, teachers and students (the adult persons) are experiencing an interesting didactic and experimental situation. The primary school pupils’ sense of discovery often produces a sense of re-discovery in secondary school students, and in teachers, too.

The learning methodology applied in the framework of secondary school preparatory lessons is focused on the idea of putting students in the situation of learning something in order to be able to teach it then to primary pupils. Furthermore, in an atmosphere that combines work and play by means of cooperative learning and peer education methodology, students experience the need to learn the correct scientific language to understand and communicate the physics contents. Students work in small groups, with the help of a technical and laboratory assistant to prepare a table of the learning path, by searching information on the web, creating didactic objects and realising experiments to be shown to primary school pupils. Each group makes also a presentation of the theoretical assumptions of its “table”, by means of multimedia tools, then discusses them in class.



The teacher’s role is to provide starting material and information to students, then to check, assist and encourage the work and the debate within the class, in a careful but not intrusive way. The teacher refers to the Lev Vygotsky’s concept of the *zone of proximal development (ZPD)* and *scaffolding teaching strategy*. In scaffolding instruction a more knowledgeable person provides scaffolds or supports another (less knowledgeable) person to facilitate the learner’s development. The scaffolds facilitate a student’s ability to build on prior knowledge and internalize new information. By this way, teen-aged students have the occasion of playing an active role in planning and supplying the “tables” to primary pupils, by creating their own “scaffold” on which set up the future knowledge.

Particular attention has been paid to encourage students to develop some aspects of their individual personality, such as self-confidence, self-esteem, sense of responsibility, spirit of enterprise, perseverance in one's aims etc.

Eventual link with the curriculum

The initiative is part of both schools' development plan, which have been presented, discussed and approved by the respective teaching staffs.

The treated subjects, like optics and sounds, and the methodology adopted are really new, and not included in the traditional school curricula at both levels (primary and secondary). In particular, with regard to secondary school, the initiative is linked to the experimental course in "multimedia and digital communication" offered by the Institute as part of its didactic curricular offer and including the optics and sounds subjects.

III- Concrete case study

a. Introduction

Pedagogical grid

Identification	
<i>Establishment:</i>	Itis Maxwell / Circolo Didattico Vinovo
<i>Teacher's name:</i>	Bardi, Francesco
<i>Subject:</i>	Physics on Show: "Secondary school students and primary school pupils together in an optics course"
Context	
<i>Class: level</i>	First year students of higher secondary school specializing in technical and industrial studies (age: 14-15 years) and fourth year pupils of primary school (age: 10 years)
<i>Number of pupils</i>	12 higher secondary school students – 43 primary school pupils
<i>Date/Hour</i>	6 April 2006 – 14:30 o'clock
<i>Duration of the observation (when applicable)</i>	1,5 hours
Learning/teaching objective	
<i>Summary description</i>	<ul style="list-style-type: none"> • Rediscover and popularize light phenomena through a number of experiences • Conceive, plan and realize significant experiences supported by a historical and multimedia approach • Train elder students to become teachers who guide and assist peers or younger pupils in carrying out simple experiments, building also simple objects
Description of the sequence	
<i>Intentions of the teacher</i>	<ul style="list-style-type: none"> • Work on the subject of light, considering different levels of understanding due to different age groups, structuring a parallel course which involves teachers and pupils of primary and higher secondary school. • Make elder students understand the importance of acquiring adequate competences in order to be listened to by younger ones and the pleasure of "knowing" and of "being" in the moment of confrontation with others.
<i>Description of the activity stage</i>	The pedagogical sequence is organised in six working groups / tables each of them dealing with a different aspect related to light phenomena, which is illustrated by a couple of (higher secondary school) students as tutors. The primary school pupils are subdivided in groups of 7-8 pupils. Each group goes from one working group / table to the next working group / table and attends the different experiments illustrated by tutors (= secondary school students). At the end of the course there is foreseen a moment of sharing and confrontation, in which is carried out a kind of group evaluation of

this experience.

The single working groups are the following:

1. **The straight and narrow path.** *How does the light travel? The direction of rays of light. Rays of light travel in a direct line from the source to the illuminated object.*

The rays of light are parallel if the source is very far away, like the sun, but are diverging if the source is close, like a lamp. The light diffusion: the smoke or dust particles diffuse the light and make visible the rays “direction”.

Tools/experiments: *paperboard tubes with a plumb-line. The light box. Camera obscura.*

2. **The human eye.** *The eye's elements: pupil, retina, crystalline lens, rods, cones. How we see the images? The eye's imperfection: myopia and presbyopia.*
Tools/experiments: the model eye.

3. **Broken images:** *how the bodies make appear the light: opaques or transparent ones. Refraction of light. The bended stick. What is big and what is small? Focus of a lens. Convergent and divergent lenses.*

Transparent objects let the light pass through without blocking it. When the ray of light passes from the air to another transparent but more dense medium, its direction changes and it gets nearer to the direction of the perpendicular line at the surface of separation. For this reason, the objects immersed in the water appear “broken” in the point of immersion, so that this phenomenon is called “refraction”.

Tools/experiments:

Experiments with a ray of light pointed at different bottles: empty, full of water, full of smoke, with milk.

The optics bench as a tool for the optics didactics.

4. **Shadow and semi-darkness.** *Punctiform and widespread sources: propagation of light, the sun and the shadows, the sundial.*

Behind an opaque object, illuminated by the light coming from a source, a shadow is formed the form of which reproduces the form of the object. The length of the shadow is much larger as higher as the object which produces it and depends on the inclination of rays of light.

Tools/experiments: sundial and gnomon.

5. **Look how many colours.** *Dispersion of light.*

Also when it seems to be “white”, the light has many colours. A transparent coloured object does not add a certain colour to the light, but lets mainly pass only rays of light of that colour. It is possible to separate a ray of light with adequate objects, by that way obtaining the colours of the rainbow. A coloured object appears as such because it diffuses mainly rays of light of that given colour. A white object diffuses rays of light of all colours, a black object does not diffuse visible rays of light.

Tools/experiments: the disk of Newton.

	<p>6. Fiat lux: where does the light originate from? The light originates from hot bodies. The energy sent out by the sun is able to heat objects and increases their temperature, this type of energy is called radiant energy because, through the rays of light, it travels in the space from the emitting source to the object which absorbs it; also a lighted bulb or a flame or a firebrand send out radiant energy, more time passes, more solar energy hits the object, more its temperature increases; the increase of temperature of an object because of radiant energy depends on the mass of the object and on the matter it is made of. Tools/experiments: three thermometers with the same temperature put in different covers and exposed to a source of light, like a lamp, for 15 minutes, differently will increase their temperature.</p> <p>7. The spectroscopy and the LED as a light. <i>The dispersion of light and the spectrum of a light source.</i> The spectroscopy is used to study the light spectrum structure. In particular it is possible to compare the continuous spectrum of a natural source of light and that striped ones of a neon lamp. Tools / experiments: spectroscopy; spectroscopy with a CD. The LED as a light is made by making move a magnet by means of a spring. By changing the time of the magnetic field, the electricity is generated into the coil.</p> <p>8. The mirrors: <i>reflection of light, the inclination of incident ray, absorption, diffusion and reflection of light. The multiple and total reflections. The cylindrical anamorphosis. True or virtual?</i> A rough surface diffuses the light in all directions, whereas a smooth surface reflects the light, i.e. reflects it in a precise direction. As regards the perpendicular at the surface in the point where the ray arrives, the direction of the reflected ray is on the opposite side and with the same angle of the incident ray. The images of objects formed by a mirror are similar but not identical to the objects, because they are specular, i.e. reversed as to the object. Tools / experiments: Different kind of mirrors: rough, smooth, opaque, concave, convex. cylindrical anamorphosis, total reflection.</p>
Pupils' output	Presentation of experiences with notice boards and drawings, summarizing schedules and didactic objects.

Intentions of the person in charge

One of the main teacher's objectives is to put students at the centre of the learning process (from simple beneficiaries to protagonists of the lesson) and to innovate teaching methodology and contents.

In particular the teacher's objectives are the following:

- ❑ To re-discover and explain the optic phenomena which regulate the everyday life by means of simple and telling experiences

- ❑ To conceive, plan and realise simple and telling experiences supported by multimedia and historical tools
- ❑ To train secondary school students as tutors who help younger or peer students in carrying out physics (optics) experiences, by means of didactic objects
- ❑ Work on the subject of light, considering different levels of understanding due to different age groups, structuring a parallel course which involves teachers and pupils of primary and higher secondary school.
- ❑ To ask significant questions to students on physics subjects using the problem solving methodology
- ❑ To make secondary school students understand how it is important and “nice” to know something and to be able to teach it

External cooperation

Some of the experiences and didactic objects realised by the secondary school students for the learning paths addressed to primary school children have been included in the travelling exhibition “The beauty of discovery”, promoted by the Science Center Project of Torino, which has travelled through many schools of the province and has been presented in occasion of the Mathematics Day at the Lingotto Gallery of Torino. The exhibition originally showed - in an interactive way - the ten most beautiful experiments in physics, according to a poll of *Physics World* readers, but it has been enlarged, when travelling through the Torino schools, with many new experiments produced by the students.

Scenario

The lesson has been held in the physics laboratory of the ITIS Maxwell, after the school hours. The students-tutors arrived in advance to help prof. Bardi to set up and prepare the tables, with all the objects and the materials needed for the experiences to be presented. Furthermore, each table is equipped with one or two posters, that explain and show the concepts that will be treated during the sequence, by means of pictures and written texts. These have been prepared in the preparatory phase of the project by groups of pupils including pupils who are not present in the observed lesson with primary school pupils.



When primary school pupils arrived, students-tutors were ready at their place to start working. Primary school pupils have been organized in groups of 8 pupils which entered separately and took place around each tables. Once all groups have been placed, the lesson officially started. When a group of pupils around a table finishes the subject exposition and presentation of this table, they are invited to move to the next thematic table. This exercise is repeated eight times in a row, so that every group of pupils visits the different thematic tables / learning paths.

From the very beginning it became evident that all the tutors lived the experience with enthusiasm and commitment: they spoke and behaved with liveliness and naturalness, trying to overcome their sense of insecurity, and to attract the children’s attention. Primary pupils generally participated in the exposition by asking questions and making comments which referred to their experience. The pupils’ questions are a great occasion for tutors to think about the phenomena they are presenting by trying to answer them correctly, if necessary even turning to the professor to be sure to provide the right answer to pupils. All in all the atmosphere generated by the meeting between students and pupils has been very positive and friendly.

b. Real progression of the session(s)

Detailed description of the session

1 The straight and narrow path.

The table has been run by the tutors Marrani and Lo Pumo (1D)

How does the light travel? The direction of rays of light. Rays of light travel in a direct line from the source to the illuminated object.

The rays of light are parallel if the source is very far away, like the sun, but are diverging if the source is close, like a lamp. The light diffusion: the smoke or dust particles diffuse the light and make visible the “direction” of rays.

Tools / experiments:

- *Paperboard tubes with a plumb-line.* To show the rays of light are parallel, primary school pupils are invited to follow the tutors in the school garden and to observe the “mark” left by the sun rays passing through the paperboard tubes.

- *The light box.* Into a box have been placed a torch and a toy soldier. Pupils are asked to look into the box through a little hole. When the torch is turned on, it illuminates the toy soldier on a painted background. When the torch is switched off, it is dark. The experiment allows the tutors to explain which are the main “actors of the vision”: the primary and secondary sources of light and the light detectors, that are light, objects and the eyes. The light links up objects and eyes, but it must be forced to “reveal itself”. The objects, when they are illuminated by a source of light, diffuse the rays and become themselves a secondary source of light.

- *Camera obscura.* By showing to pupils a simple camera obscura, the tutors can explain to them that the light travels in straight lines and that, when some of the rays reflected from a bright subject pass through a small hole in thin material, they do not scatter but cross and reform as an upside down image on a flat surface held parallel to the hole.

2 - The human eye.

The table has been run by the tutors Addesi and Andreotti (class 1B).

They showed to children the eye’s elements, as there are pupil, retina, crystalline lens, rods, cones, and their functions, by means of a model which reproduces the eye structure. They explained to pupils that the images we see reach the retina “upside down”, and are transmitted through the optic nerve to the brain which turns it over, so that we see the objects in the right way. Tutors also spoke about the most common eye imperfections: the myopia, that is when people do not see well distant objects, since the rays of light focus before and not on the retina, and presbyopia, that is when people do not see well close objects since the rays of light focus behind and not on the retina. Both imperfections can be corrected by means of convergent and divergent lens.



Tools / experiments:

The model eye allows tutors to illustrate how the eye works. The model is made by unbreakable materials, and its structure is capable of being deformed, so that it allows to modify the position of the retina and the shape of the crystalline lens. The model is equipped

with lenses, in order to show how the most common eye imperfections can be corrected.

3 - Broken images.

The table has been run by tutors Agostara and Ruffino (Class 1B).

Tutors explained to children how the bodies make appear the light. In particular they illustrated the difference between opaque and transparent objects. The opaque objects are those which do not let the rays of light pass through. The transparent objects let the light easily pass through.

Students showed to pupils that when we immerge an object in the water it appears “broken”. That is because the rays of light, by passing from the air to another transparent but more dense medium, change direction and get nearer to the direction of the perpendicular line at the surface of separation. This is the occasion to explain what “refraction” is.

Tools / experiments:

Tutors show this concept by means of simple experiences: by pointing a ray of light at an empty bottle and at a bottle full of smoke. They also pointed the ray of light at a bottle of water, and then they made the bottle opaque by adding milk.

Tutors also took advantage of an **optics bench**, that is a system which allows to verify and apply some optics laws, i.e. the geometrical optics, by means of standard tools, as lenses, mirrors, apertures, etc. Tutors explain to pupils that the light travels in straight lines, by bringing into line a light source, a sort of mask reproducing an arrow with its point turned up and a screen.

4 - Shadow and semi-darkness.

This table has been run by tutors Milazzo (1D) e Corsetto (1B).

Students talked about the shadow and the semi-darkness, as we can see everyday, just when the sun addresses its rays to objects, i.e. the trees in a park. This is an occasion to explain the difference among punctiform and widespread sources of light. In fact when there is a punctiform source of light, that is a concentrated beam, the shadow produced by the objects is very sharp. Whereas, when there is a widespread source of light, the shadow produced by the objects is more shaded and there is a mix of darkness and semidarkness. Tutors showed this concept to pupils by means of a simple experiment which consists in casting a punctiform or widespread ray of light on a opaque object (a little ball) and in observing its shadow when it is projected on a screen.

They also showed to students how the length of the shadow depends on the size of the object which produces it and on the inclination of rays of light.

Tools / experiments:

For this demonstration they make use of the sundial, by illustrating pupils how it can be used and how it does work. They explained that the sundial was used in the past for measuring time by the position of the sun. In fact the sun casts a shadow from a “gnomone” on a flat surface marked with the hours of the day. As the position of the sun changes, the shadow changes its length and position, indicating by that different hours of the day. The first gnomone in history was... the Neolithic men, which soon started to observe and measure the shadow cast by placing himself behind the sun, to know how long it was until the sunset.

5 - Look how many colours.

The table has been run by tutors Martignago e Amendola (1D).

Tutors dealt with the concept of dispersion of light, by explaining pupils that even if it seems to be “white”, the light has many colours. A transparent coloured object does not add a certain colour to the light, but lets mainly pass only rays of light of that colour. It is possible to separate a ray of light with adequate objects, by that way obtaining the colours of the rainbow. A coloured object appears as such because it diffuses mainly rays of light of that given colour. A white object diffuses rays of light of all colours, a black object does not diffuse visible rays of light.

Tools / experiments:

Tutors made use of the *Newton's colour disk* to show to pupils that white light can be obtained as the sum of the rainbow colours. The disk is formed of various sectors painted with the rainbow colours. It is used with the rotating machine. Because of the persistence of the image on the retina, the various colours superimposed give the sensation of white.



6 - Fiat lux

The table has been run by tutors Rondina (1D) and Comazzi (1B).

Tutors try to answer with pupils the question about the origin of light, by observing that a flame, a bulb, a gas lamp, and all the objects that produce light are “hot bodies”. So we can say that the light originates from hot bodies. The sun is the biggest source that supplies light to the earth. The energy sent out by the sun is able to heat objects and increases their temperature.

This type of energy is called radiant energy because, through the rays of light, it travels in the space from the emitting source to the object which absorbs it; more time passes, more solar energy hits the object, more its temperature increases; the increase of temperature of an object because of radiant energy depends on the mass of the object and on the matter it is made of.

Tools / experiments:

Tutors made a simple experiment by putting three thermometers with the same temperature in different covers: one in a black cover, one in a tinfoil cover, one without a cover. If we expose the three thermometers to a source of light, like a lamp, for 15 minutes, we can see that each of them will increase its temperature depending on the cover they are wrapped in.

7 - The spectroscope and the LED (Light-Emitting Diod) as a light

The table has been ran by tutors Fusco (2A), Appiano (3A) Mafodda (1A) and Martini (1D).

The *spectroscope* is used to study the light spectrum structure. In particular it makes possible to compare the continuous spectrum of a natural source of light and the striped ones of a neon lamp. The collimator and the spyglass are placed on the branches of an L-shaped tool, supported by a tripod. Between the collimator and the spyglass there is a prism, kept into a cylindrical wrapper, with 2 apertures at the collimator and spyglass level. The light passes through the collimator and reaches the prism that disperses it. Then the light meets with a specific inclination the glass, by which it is partly reflected and refracted. By this way, parallel rays are formed and gathered into the eyepiece, where it is possible to see the interference fringe.



A *spectroscope with a CD* has been realized by using a paperboard box with a hole on a side, in which it has been inserted a paperboard tube as a viewfinder. On a lateral side it has been created a fissure to let the rays of light pass through. On the opposite side there has been put a 45° inclined CD, that gathers and refracts the rays of light which come into the box. By this way it is possible to observe the decomposition of light phenomenon, which depends on the fact that the rays are reflected by the grooves of the CD surface, by covering different distances. Depending on the distance covered, the rays meet by increasing or loosing their strength. The interference may be constructive or destructive

according to the wavelength, that means the different colours are visible in different closed portions of the CD, and the wavelength of each colour can be measured.

Special glasses to see the colours of the light. Each colour has a different wavelength, from the blue (400 nanometres) to the red (700 nanometres). The special glasses take advantage of the diffraction grating to make visible the colours' spectrum. The ray of light, passing through the grating, is diffracted into many rays (while the main ray is continuing its travel) with an inclination depending on the different wavelengths: the blue colour has the minor angle inclination, then follow the other colours with bigger angles. In the special glasses there is a double grid (horizontal and vertical) which creates multiple images.

The *LED (Light-Emitting Diod)* as a light is made by making move a magnet by means of a spring. By varying the magnetic field with time, electricity is induced in the coil. By this way, the LED placed in the lamp holder of a bike spot is turned on.

8 -The mirrors

The table has been run by tutors Aliano, Chinaea (1D) and Labate (1B)

The table is about the reflection of the light and the mirrors. Tutors show to pupils *different kind of mirrors*: smooth, rough and opaque ones, and they explain to pupils what happens when a ray of light comes up against the different surfaces, that is the ray of light is reflected in a particular direction (smooth surfaces), or in all directions (rough surfaces).



Tools / experiments:

Then tutors explain that the images in the mirrors are similar but not identical to the objects reflected, because they are specular, i.e. reversed as to the object. They show to pupils some words written upside down, and ask to pupils to read them. Of course they cannot (although some can...). But if they watch the same words reflected in a mirror, they become easily readable. Leonardo da Vinci made use of this trick to keep his notes secret.

And what happens when there is more than one mirror? This phenomenon is called *multiple reflection*. It can be shown by means of a kaleidoscope, which has been built by tutors using three triangular mirrors (glass-plastic surfaces) and a sheet that lets the light passing through (a greaseproof paper). The kaleidoscope realized for this occasion is a lengthened prism, made by three 60° inclined reflecting surfaces fixed with an adhesive tape, so removable, and containing coloured objects. The kaleidoscope may be handled round its vertical axis and the observation may be done through the forth - empty - side. The ray of light is reflected by the three mirrors, and the image of the objects is reproduced many times, so that incredible mechanical drawing are created. When two mirrors are put one in front of the other, the images created by the reflection are endless, infinite, because each mirror reflects another mirror,

which reflects another mirror, which reflects again. The effect is greater when using different kinds of mirrors, like concave and convex ones, that deform the image making it smaller or bigger than it is.



The mirrors may be used also for a sort of magic: that is the *cylindrical anamorphosis*. In the cylindrical anamorphosis a painting or drawing that is distorted becomes recognizable when viewed with a cylindrical mirror placed upon the picture in order to reveal the distorted surface.

Also the *optical fibres* seem to be magic: they are thin rods of glass in which the ray of light, once it has got in, gets stuck and keeps to be reflected until the end of the rods. That is due to the refraction phenomenon: when a ray of light passes through the division surface between two materials having a different index of refraction, it is both refracted and partly reflected. If the angle of incidence of the ray on the surface is bigger than the limit-angle, the ray is totally reflected. This is called *total reflection* and happens in optical fibres. In optical fibres the ray of light comes into the fibre with a specific angle and it is reflected all along the rod (drawing a sort of zigzag line) till the end.

Working documents:

Please find attached a document containing the students' reports, by means of which the teacher gathered the students' impressions/feelings on the initiative.

c. Open conclusion

Although the teachers try to plan the learning path in details, what may happen during the meeting between students and pupils it not really predictable. In fact, for both tutors and pupils this situation is new. For the first time tutors have to talk in public, and they did not have much time to rehearse. Of course they are prepared, they know very well the matter of their own table, often they have written a short text to remember the sequence and the speech to be done in front of pupils. Nevertheless, the excitement of having a real listening audience may make them feel insure and uneasy. All in all we observed that they have been very able to explain and to show to pupils objects and experiments.



Also the pupils of primary school have been very interested in following the activities, by asking questions and making observations on the matter. The interest and the participation are certainly due to the training activities in this specific field they have done with their teachers during the months before, in order to get prepared for the event.

Regarding the sequence, there have been some changes in the tables presented, as well as in the experiments proposed, in contrast to the description which the teacher transmitted in advance by means of the pedagogical grid, but the general outline of the sequence has been run as expected.

Objectives achieved

To understand better the value of the initiative, and how it has been successful, it is important to keep in mind that tutors are students of the first year of technical secondary school, and they did not study optics before, some of them do even not have good marks in physics.

The commitment of young students demonstrated in the teaching of primary pupils is an evident sign of the success of the initiative, since its real objective is to make students play an active role in school.

Science education proves to be a fertile ground (not too difficult, as it is usually considered) for initiatives aimed at motivating youngsters to study. By starting appreciating physics, as they showed to do, students of technical secondary school may discover new interests and new possibilities for the future.

Concerning the pupils of primary school, the objectives have been fulfilled, because they have been approached to the physics subject in an entertaining way, while usually in primary school these subjects are not studied at all. By this way, also thanks to the preparatory work done with their teacher during the school hours, pupils soon start to acquire a “scientific attitude”.

Sufficient results

The investment to prepare the session has been very high, being the teacher in charge of the initiative alone in doing the work with secondary school students. He took advantage occasionally of the help of some colleagues, but of course he bore by himself the responsibility of the initiative.

Finally, all the participants (primary school teachers, students, tutors, observers, etc.) have been really satisfied with the initiative.

Added value

The idea on which is based the initiative is to show to students how physics can be “exciting” and “beautiful”, by taking advantage of the historical and expository aspect of science, as well as computer simulations, hands-on experiences etc. Playing the role of tutors and assuming the responsibility of teaching helps students growing. They also experience the usefulness of their own knowledge and the pleasure of teaching with great satisfaction. Moreover, the initiative has also the added value of offering guidance for secondary school students’ study choices.



Another important objective is to stimulate the primary pupils’ passion and attitude for science by offering them playful experiences in this field.

Obstacles

The main obstacle in carrying out the initiative seems to be the school environment, which even in a school that supports many interesting projects in science education (such as RADON and BEZIER) is sometimes not really favourable and encouraging. The initiative has been realised thanks to the teacher’s personal commitment, and in spite of financial costs and problems of time. But what really may cause problems is that projects involving technical course students seem to be less considered than others. Furthermore, the general aim of making students play an active role in school activities, if not shared at all levels and among all colleagues, may be obtained only partly.

Weak points

Some weak points pointed out by the teacher in charge are:

- Not all secondary school students have been able to study autonomously and to participate with a sense of responsibility in the initiative.
- Not all secondary school students have been able to follow a learning path that goes from the everyday life situation to the virtual simulation or multimedia representation.
- Some students had difficulties in involving classmates which did not directly participate in the initiative.
- Teachers had difficulty in finding effective evaluation criteria and methodology.

Strong points

Nevertheless, there are many strong points which help to overcome the difficulties:

- Making use of an experimental teaching methodology which stimulates students' interest and curiosity towards physics phenomena.
- The need to create didactic objects to illustrate to primary school pupils physics phenomena, which allow to combine the theoretical and the hands-on approach.
- The occasion offered to the teachers to conceive and realise new learning paths which better follow the different development and cognitive stages of secondary school students and primary school pupils.

Prerequisites for transferability

The most important prerequisite for transferring the initiative is the link between the different school levels, primary and secondary. This connection can be more or less developed, i.e. teachers can work together on the same learning path, at different levels (training for teachers, pupils and students), or they just meet during the exhibition. Anyway, the teacher in charge of the initiative in the secondary school must have a strong organisational ability, to put together the students' group and to plan in detail the sequence, providing instructions for students while giving them also the possibility to act as they prefer.

The balance between the students' freedom and creativity and the order of the sequence (which guarantees the learning contents of the activity) is the most difficult element to be transferred, as it depends on the peculiarity of each single actor.

To repeat the initiative the school must have a physics laboratory large enough to house 40 people (tutors + pupils) and all the tables and materials.

Possible improvement

The initiative would be improved by taking advantage of a strong cooperation among the teachers of the secondary school, which may contribute in different manners to achieve the project's objective.

Moreover, primary teachers who are involved with their classes in the initiative suggested that the "Physics on stage" initiative should become a permanent and stable element of the school year, with a number of regular meetings on different physics subjects between primary pupils and secondary school tutors, and not just a one-off event. Of course, better results may be obtained also with a larger investment of funds, time and support at school managers' level.