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# NEW EDUCATIONAL PERSPECTIVES ON SPECTROSCOPY IN THE ROMANIAN HIGH SCHOOL

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*Abstract.* Today, the Spectroscopy is not very well represented in the Romanian Physics curriculum for high school. We are trying to design a blended learning strategy to facilitate the understanding of the spectroscopic investigation phenomena. Our perspective begins with a short theoretical consideration of what light means, as for example, what is the role of the quantum transitions in the absorption and the emission of electromagnetic radiation. We are intending to use Inquiry-based method in studying Spectroscopy. So, we will try to lead the students to find the answers to the questions as the following: What is light? How is the light emitted or absorbed? What are the quantum transitions? How can we detect the emission of radiation? What is a spectrum? How can we obtain spectra with a classical spectrometer? How can we register spectra with a digital spectrometer? The students will notice the emission spectra, or pattern of wavelengths (atomic spectra) emitted by different elements in the lab. Some of the challenges will be the verification of the Lambert-Beer law and the absorption spectra of a chlorophyll solution. We are trying to find out what type of light are the green leafs using. During this kind of didactic activities we have tested the learners’ satisfaction by using two questionnaires.

*Key words*: spectroscopy, inquiry-based method, spectra, light.

## 1. INTRODUCTION

Recently, there has been a considerable interest in new experiments and new pedagogical approaches for teaching spectroscopy at any level. For example, the Spectroscopy Letters has published three special issues in 2004 (Volume 37, Issues 2–3), 2007 (Volume 40, Issue 3), and 2010 (Volume 43 Issues 7-8) that include research papers, descriptions of innovative laboratory experiments, and innovative approaches to spectroscopy pedagogy [1-3].

In the attempt to revive the student’s interest in studying Physics, we created and tested new approach strategies to the topic entitled Spectroscopy. This topic is based on mixing (in variable proportions) expositive methods – the traditional ones or assisted by Java applets, with interactive experiments where the students work together while studying spectra. The experimental work in these strategies took place not only in virtual environment, but also at the Physics Laboratories of the “Grigore Moisil” High School in Bucharest. We also used some experimental demonstrations at the Atomic Physics Laboratory of the Physics Faculty, University of Bucharest.

We have considered that our educational activity is best handled with a blending of several methods, from simple self-review and self-study, to collaboration and interaction among students and instructors connected in reality or via Internet [4].

Before and after these didactic activities, some questionnaires were applied to the students, regarding the strategy that had been used, to evaluate their satisfaction by the affective response and the motivation acquired during the experiment.

## 2. ABOUT TEACHING PHYSICS TODAY

The classic, stiff nowadays education, based on mechanical learning, needs a great transformation into a modern education, intelligent and creative, where the teacher and the student cooperate [5, 6, 7]. Undoubtedly, the difficulties start to appear soon: the teacher tends to focus on transmitting information, while the student tries to learn it by heart, to assimilate and reproduce this knowledge. The traditional methods cannot make all the students think at the same pace with their teacher, while the teacher has only superficial and limited knowledge about the students’ information and the way they memorize. The students do not realize how well they have understood the taught subject and whether they can independently apply the new-acquired knowledge [8].

A wide range of constructivist pedagogies now are available to the physics teacher, most of which have shown some success compared to traditional teaching styles [9]. Learning is not the exclusive result of teacher’s actions any more. Being a complex cognitive process and a social intra and interpersonal activity, learning becomes difficult to observe and measure. On the other hand, its distribution in space and time differs from one person to another, and the best moment for learning cannot be anticipated and imposed any more. At best, it can be located in space and time the activity (lesson) in the classroom. Therefore, a differentiated approach becomes necessary for each student.

The actual Physics curriculum demands the students to acquire the following competences:

- ✓ The understanding and explanation of a number of Physics phenomena, some technological processes, the functioning and utilizing some technical devices in every-day life

- ✓ Experimental and theoretical scientific investigation applied in Physics
- ✓ Communication
- ✓ Protection of self, the others and the environment [10].

But the percentage of the learning activities (presented in the same curricula) that would form these competences is very low. Unfortunately, a great accent still lies on the academic structure of the suggested content. Inter-disciplinary research is still not very well defined. The act of connecting knowledge to real world is mostly made through activities implying natural and technological applications of the studied phenomena or device. The number of experimental investigations and case studies on actual problems of the world is relatively small. At the time being, the goal of the seven years of study of Physics (for those who attend the courses of theoretical and vocational classes) is represented, unfortunately, only by the graduation with higher grade at the Baccalaureate Exam and, presumably, at the admission examination for the Faculty.

In most cases, Physics is a hard "academic" subject, whose understanding requires students to make great efforts. Although it is mainly an experimental science, the teachers are going further and further away from the experiments even in the school labs. There are multiple causes: the laboratory becomes classroom, the devices do not exist anymore or they are not working, the lack of interest and effort, etc. Or it is even the today curricula or textbooks that do not give support to this type of investigative activities.

Although, according to Pedagogy treats, organizing didactical experiments at a modern technology level, both as equipment, installation etc. and as execution, it is needed to prepare the students within the requirements of contemporary science, techniques, production, and investigation and design [11].

## 3. NEW APPROACH ON LEARNING SPECTROSCOPY

For the study of Spectroscopy we will make reference to the Physics curriculum for the 12th grade classes. Today curriculum, on the topic called Spectra demands the development of the following scientific competences [10]:

- ✓ The experimental investigation of emission/absorption spectra – the continuous spectra, band spectra, discrete spectra (qualitative);
- ✓ Classification of spectra depending of different criteria;
- ✓ Qualitative analysis of discrete spectra of hydrogen/hydrogen-like ions – discrete structure and regularity.

There is even an obligatory laboratory work, entitled *Qualitative Study of Spectres – Continuous Spectre, Band Spectres, and Discrete Spectres*. This topic and the laboratory work are treated in the textbook "Physics – students' book for the 12th grade, F1+F2", All Educational Publishing Company, 2007, authors C. Mantea and M. Garabet, authorized by the MECT speciality committee [12]. The same topic also needs to be treated in Physics curriculum, Theoretical Classes, humanistic profile, for the 11th grade classes approved by the Ministry Order No. 3252 / 13.02.2006.

We enlarged this content in the textbook "Sciences – students' book for the 11th grade", BicAll Publishing, 2006, authors M. Garabet, S. Fătu and J. Cîrstoiu, authorized by MECT speciality committee. This intervention was needed in order to approach the topic of "Experimental Proofs of the Expansion of the Universe" [13]. We suggest a new approach to Spectroscopy, so that the allocated number of classes should be higher than it is at the moment. The knowledge and, implicitly, the act of learning, are built on every-day experience. In the old approach, the Spectroscopy questions, or the atomic models and quantum transitions are difficult for student's understanding. We suggest a mostly experimental approach to this topic, starting from the qualitative analysis of emission and absorption spectra and continuing with notions regarding spectral and quantitative analysis. We consider that primarily formulating problems for study by launching scientific hypothesis, in order to be tested for approval, may incite the curiosity and interest of students. At the same time, alternating learning through discovery and problems will assure the student's growing involvement in the act of learning. Learning will start from reinforcing notions about the electromagnetic nature of light, dispersion and diffraction of light. Starting from here, we will try to address the students some questions which would lead them to understand the information involved. Didactically, inquiry-based learning represents a method of acquiring new information along with transforming it into useful knowledge. If the so-called traditional methods emphasize listening and repeating the expected answers, in Inquiry-based learning, the accent moves toward the context which determines the questions [14]. We preferred to use interpretative questions which force the act of understanding the consequences of the presented experiments. Related to the specific observations, there were introduced the questions which would generate hypothesis. We will present them in due time. Once you have learned how to ask relevant and appropriate questions, you acquire a superior capacity of learning and no one can keep you from learning whatever you want or need to know [15]. Moreover, recent years have seen a growing call for inquiry to play an important role in science education [16, 17]. This call for inquiry-based learning is based on the recognition that science is essentially a question-driven, open-ended process and that students must have personal experience with scientific inquiry to understand this fundamental aspect of science [18].

## 4. THE EXPERIMENTAL ACTIVITY OF THE STUDENTS

The experimental activities of the students have deployed in the school lab, and a few in the Atomic Physics undergraduate Faculty lab, by posing and refining research questions, planning and managing an investigation, analyzing and communicating results. Participation in inquiry can provide students with the opportunity to achieve three interrelated learning objectives: the development of general inquiry abilities, the acquisition of specific investigation skills, and the understanding of science concepts and principles. By providing learners with the opportunity to pursue answers to questions, inquiry activities can enable learners to uncover new scientific principles and refine their pre-existing understanding of scientific principles in the answers that they construct. Inquiry activities can give learners the opportunity to apply their scientific understanding in the pursuit of research questions. The need to apply scientific knowledge can require a learner to reorganize and re-index it so that will support its future use. The application of existing knowledge can also reinforce it and enrich its connections to other knowledge [19].

### 4.1. WHY DOES THE HUMAN EYE HAVE THE HIGHEST SPECTRAL SENSITIVITY AT GREEN RADIATION?

Analysing the emission spectra (obtain with an Ocean Optics PC 2000 spectrometer in the Grigore Moisil High school Physics lab, thanks to the Center for Science Education and Training), of the usual spectrum sources (the Sun, incandescent light bulbs, flames) will lead to noticing continuous spectra made of a multitude of lines and molecule bands from the burning gas inside the flame. The spectral density of the Sun radiation is dominated by the green and yellow colours. This explains why the human eye is more sensitive to green and yellow light than to red and purple light.

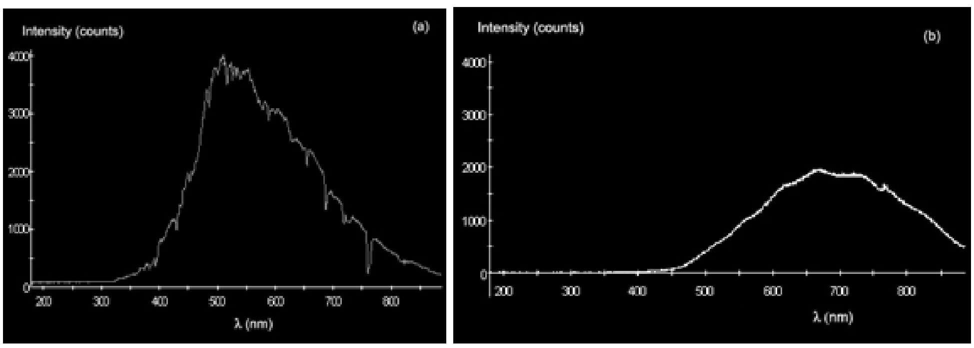



Fig. 1 – Solar emission spectrum (a) and emission spectrum of an incandescent candle-lamp (b).

## 4.2. WHAT SIMILARITY IS BETWEEN THE FOLLOWING TWO SPECTRA?

Both figures illustrate the nearly monochromatic emission of a laser diode, (a) recorded with a simple prism spectrometer (in the “Grigore Moisil” High school Physics lab, that can be usually found in high school laboratories), (b) with a digital Ocean Optics PC 2000 spectrometer.

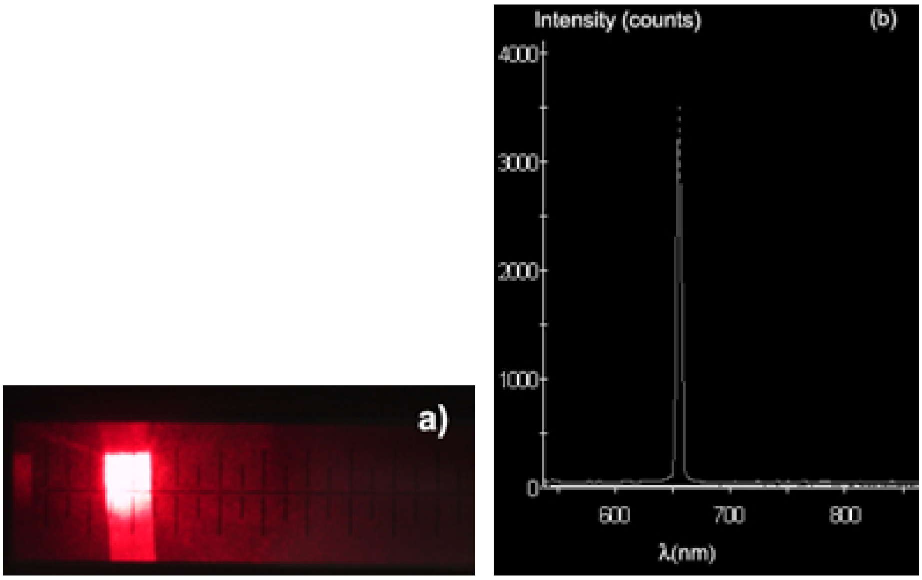
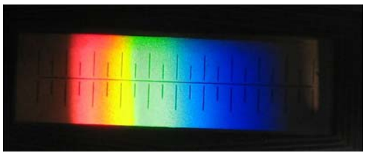


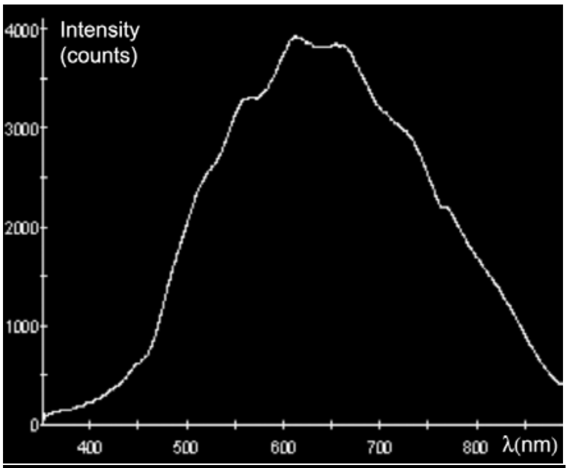

Fig. 2 – The generated radiation of a laser diode source. The colored versions could be accessed at http://www.infim.ro/rrp/

## 4.3. HOW DO YOU EXPLAIN THE DISAPPEARANCE OF SOME BANDS FROM THE FOLLOWING PAIRS OF SPECTRA?

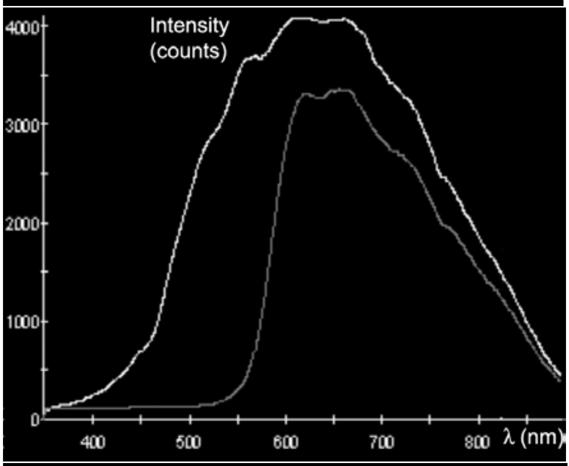
If the radiation that comes from a source that emits a continuous spectrum passes through an absorber environment, in its spectrum will appear lines or dark bands characterizing the absorbing substance. The white curve from pictures in the Fig. 3 represents the emission spectrum of an incandescent light bulb spectrum of the spectral lamp, and the following curves represent the same spectrum using different filters, digitally registered with an Ocean Optics PC 2000 spectrometer. A filter is transparent to a specific colour, absorbing all the others colours.



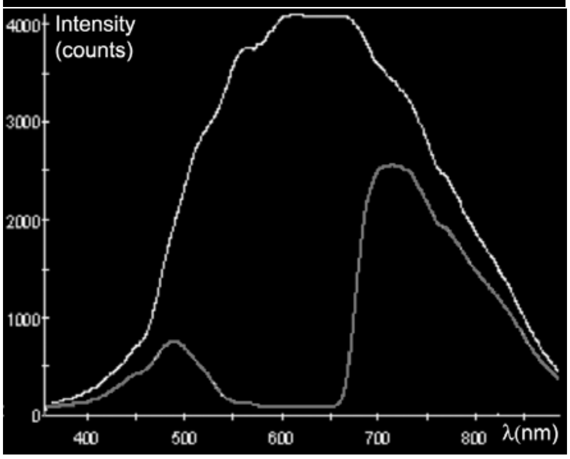
Incandescent light bulb (a)

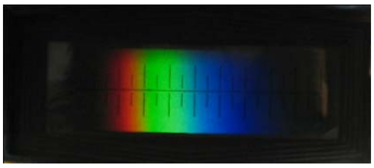



Incandescent light bulb with red filter (b)

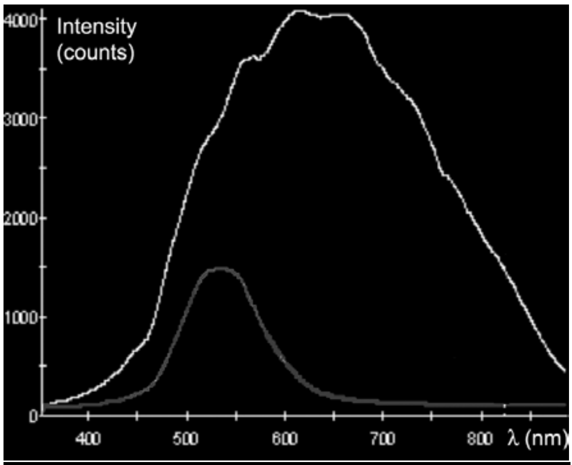



Incandescent light bulb with blue filter (c)





Incandescent light bulb with green filter (d)




Incandescent light bulb with yellow filter (e)

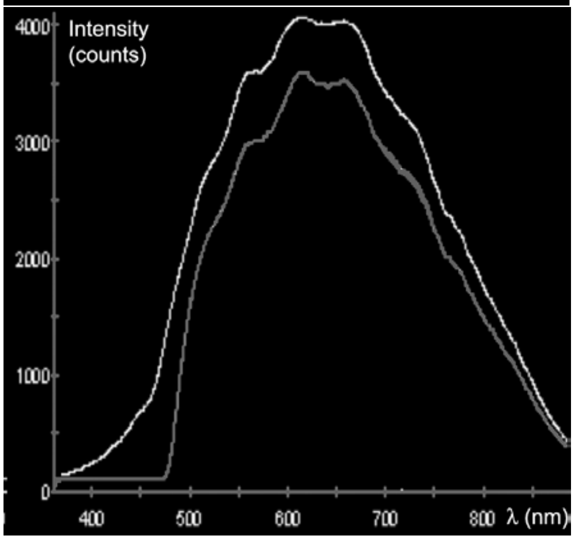



Fig. 3–The emission spectrum of an incandescent light bulb with different filters (a,b,c,d,e). The colored versions could be accessed at http://www.infim.ro/rrp/

The filters used in this experiment can be usually found in high school laboratories. It is easily to observe in the above figures that they have not a good quality. The best quality among them has the green filter (Fig. 3d).

## 4.4. WHICH ELEMENT HAS EMISSION LINES IN THE NEXT SPECTRUM?

Atomic emission spectroscopy is one of the most important techniques of elemental analysis [20, 21]. When introducing fine salt particles in a flame, it gets a yellow colour. The emission spectrum of the flame becomes as in Fig. 4. The sodium chloride dissociates due to the intensified thermal agitation within the flame, which causes the apparition of emission spectral lines of sodium atoms. The students compared the recorded spectrum with the spectra obtained in virtual environment. Within the limits of experimental errors, the yellow doublet of sodium atoms appears at 587 and 588 nm. Theoretically, the values are 589.0 respectively 589.6 nm [22].

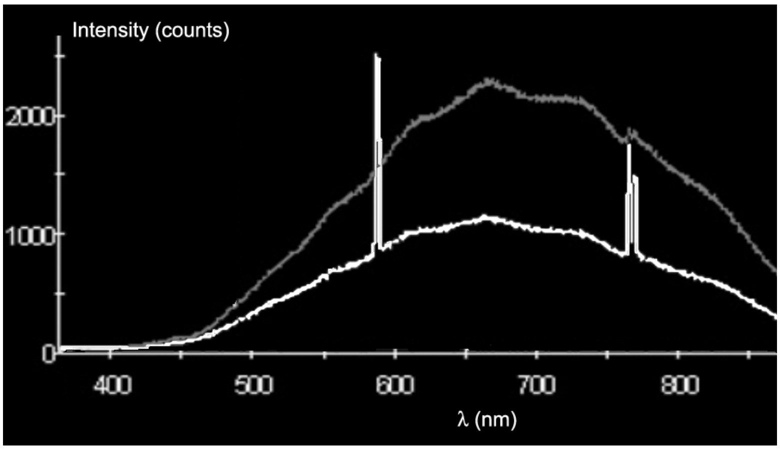



Fig. 4 – The spectrum of a candle flame (gray) and of the same flame sifted with salt (white).

We mention that the content of this lesson can be accessed by any interested user through its conversion into e-learning format. The digital spectrometer Ocean Optics PC 2000 makes possible saving the signals obtained in widely known formats as Microsoft Excel. This way, they could easily reach the interested educational users.

### 4.5. WHY DO THE FLUORESCENT LAMPS CONSUME LESS ELECTRIC ENERGY THAN THE INCANDESCENT LIGHT BULBS?

From the analysis of the two types of lamps spectra, the students compared their emissions to explain the reduced power demand of the compact fluorescent lamp.

### 4.6. WHAT PARTS OF THE VISIBLE SPECTRUM DO THE PLANTS' GREEN LEAVES REFLECT?

We tried to observe the reflected radiation of a ficus carica leaf lighted by a white-light source, as the spectrometer's source. It is generally known that plants absorb radiations from the blue, respectively red zones of the visible environment, in order to realize the photosynthesis. We captured the source-radiation reflected on aluminium foil and the radiation that was reflected from the ficus leaf with an Ocean Optics PC 2000 spectrometer. We can notice that the green parts of the visible spectrum are reflected by the green leafs of the plants.

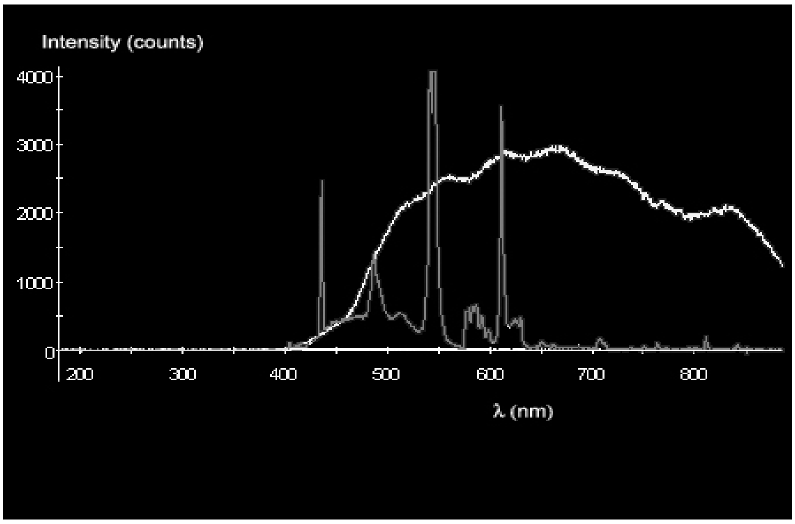



Fig. 5 – Incandescent (white) and compact fluorescent lamp spectra (gray).

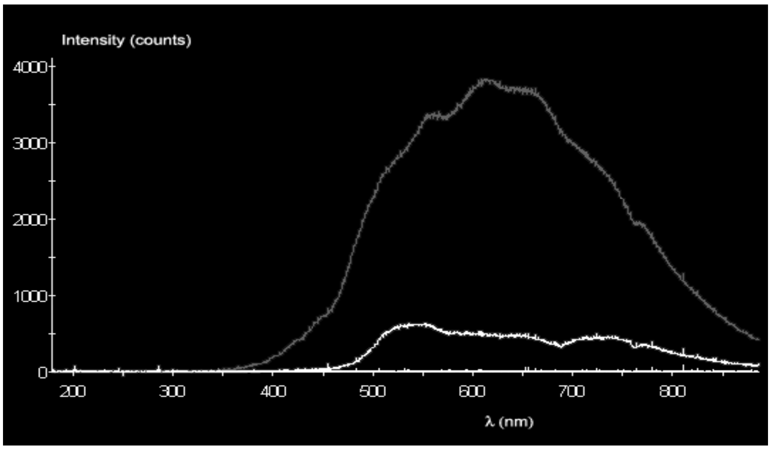



Fig. 6 – White light reflection on aluminum foil (gray) and on ficus leafs (white).

## 4.7. DOES WATER ABSORB THE INFRARED RADIATION?

We gradually recorded the emission spectra of a certain source through air and through a fine layer of water with an Ocean Optics PC 2000 spectrometer. The students are required to explain the difference between the two spectra.

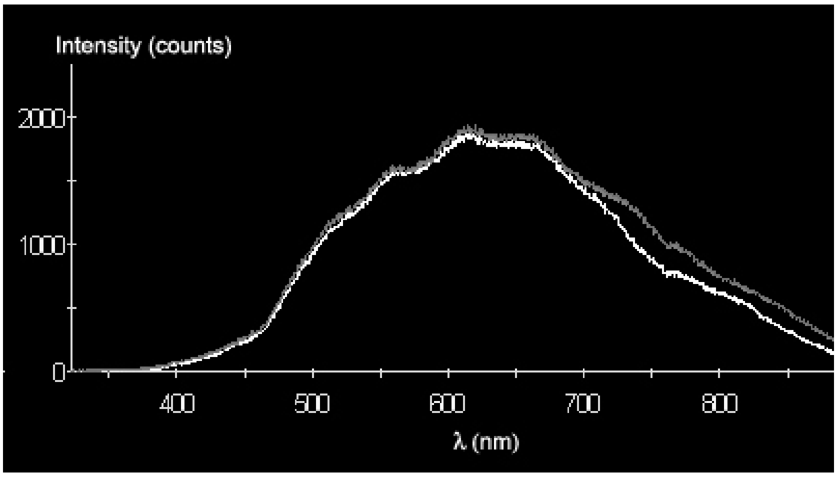



Fig. 7 – Emissions of an incandescent light bulb through air (gray) and through a layer of water (white).

## 4.8. WHAT RADIATIONS OF THE VISIBLE SPECTRUM ARE ABSORBED BY GREEN LEAFS DURING THE PHOTOSYNTHESIS?

We prepared a chlorophyll solution in ethyl alcohol using spinach leafs.

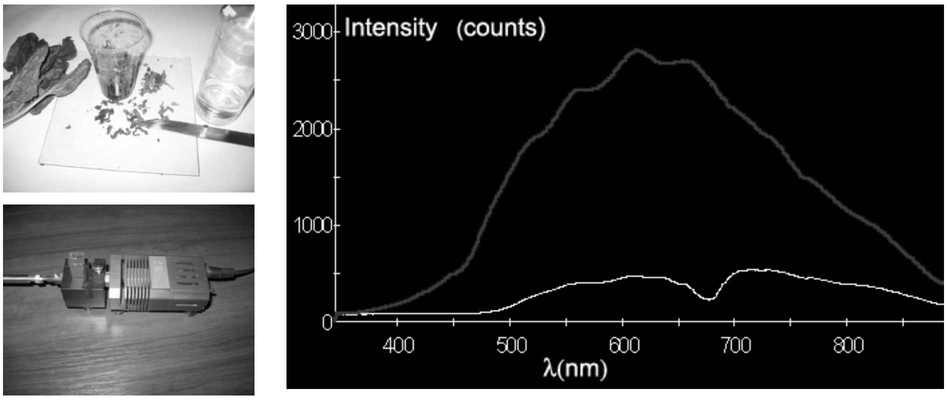



Fig. 8 – The preparation and the registering of chlorophyll solution from spinach leafs. The emission of the spectrometer's lamp (left down) through air (gray) and through chlorophyll solution (white).

The students analyzed the emission spectra of the source, respectively of the chlorophyll solution from spinach leafs. At the same time, they analyzed the absorbance and transmittance of the chlorophyll solution, making correlations between the spectra obtained with an Ocean Optics PC 2000 spectrometer.

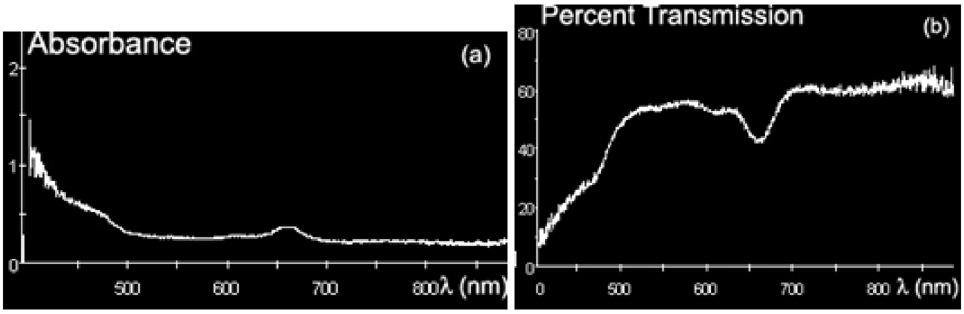



Fig. 9 – Absorbance (a) and percent transmission (b) within the chlorophyll solution.

## 4.9. HOW CAN WE IDENTIFY AN UNKNOWN SOLUTION CONCENTRATION?

Every substance has a unique absorption spectrum. The maximum absorption represents both the peak and the wavelength that corresponds to the maximum value. There can be one or more maximum absorption values. The number of maximum values and the general form of the curve represent the qualitative characteristics which define the substances. We started from the Lambert-Beer law in order to discover the best way to identify the concentration value of an unknown solution. We prepared water solutions with different CuSO4 concentration, starting from a 0.1M. Then we recorded their absorbance with an Ocean Optics PC 2000 spectrometer.

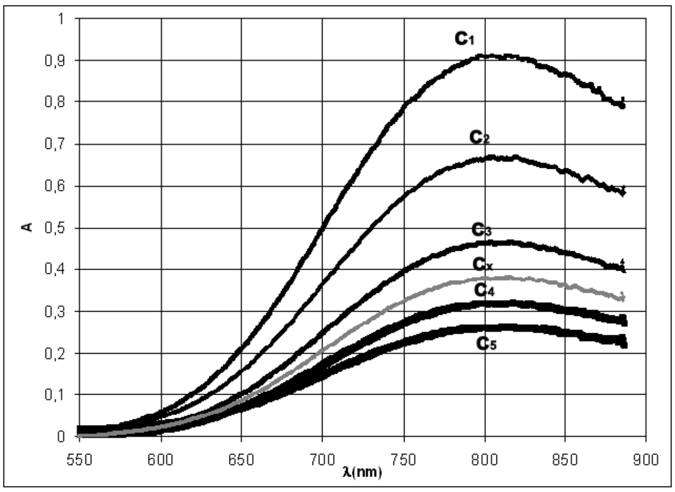



Fig. 10 – Chlorophyll solution absorbance at different concentrations. The concentration values $c_i$ are illustrated in Fig.11.

From the signals' analysis, the students identified the wavelength corresponding to the maximum values of the absorption spectrum. Consequently they recorded the absorption values vs. concentration. The absorbance dependence on concentration was situated, within the limits of experimental errors, on a straight line. The unknown concentration of the solution could be determined using the calibration line (Fig.11).

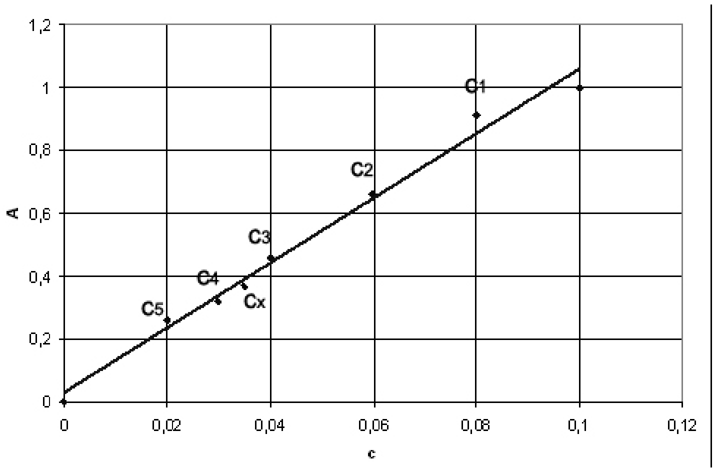



Fig. 11 – The absorbance dependence on concentration.

4.10. WHAT HAPPENS IN A LOW-PRESSURISED DISCHARGING TUBE?

The students can make correlations between plasma at low temperatures in low-pressurised gases (which become great conductors if is applied a high enough voltage) and the spectral mark of the gas. For obtaining the plasma, it is necessary a single electron that has a sufficient energy to produce an ionization process. The resulted electrons are accelerated in electromagnetic fields. In order to the ionization process to take place again, the energy they acquire after two consecutive impacts has to be larger than the ionization potential of the corresponding atoms. This way, there takes place an avalanche multiplication of ionizations, and the plasma lights up. To maintain it, it is necessary that, after recombining and getting emissions of electrons at the cathode, at least the initial electron to be renewed.

## 5. THE ANALYSIS OF THE SATISFACTION LEVEL OF 12TH GRADE STUDENTS

This study's target was to analyse the satisfaction level of 12th grade students involved in the earlier described learning activities. The satisfaction pre-questionnaires regarding the learning of Physics were applied on 80 students of three 12th grade classes, mathematics-informatics specialisation, from "Grigore Moisil" High school in Bucharest, on November 2010.

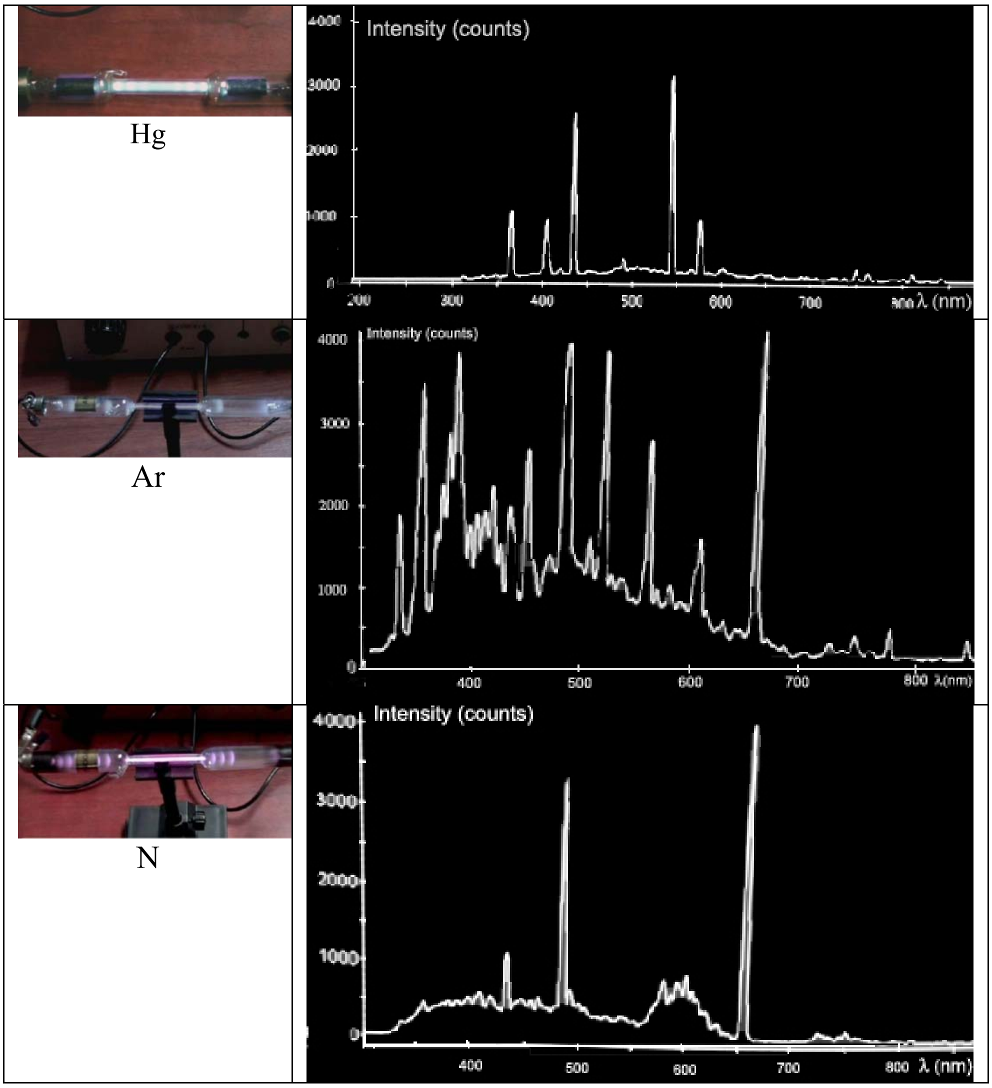
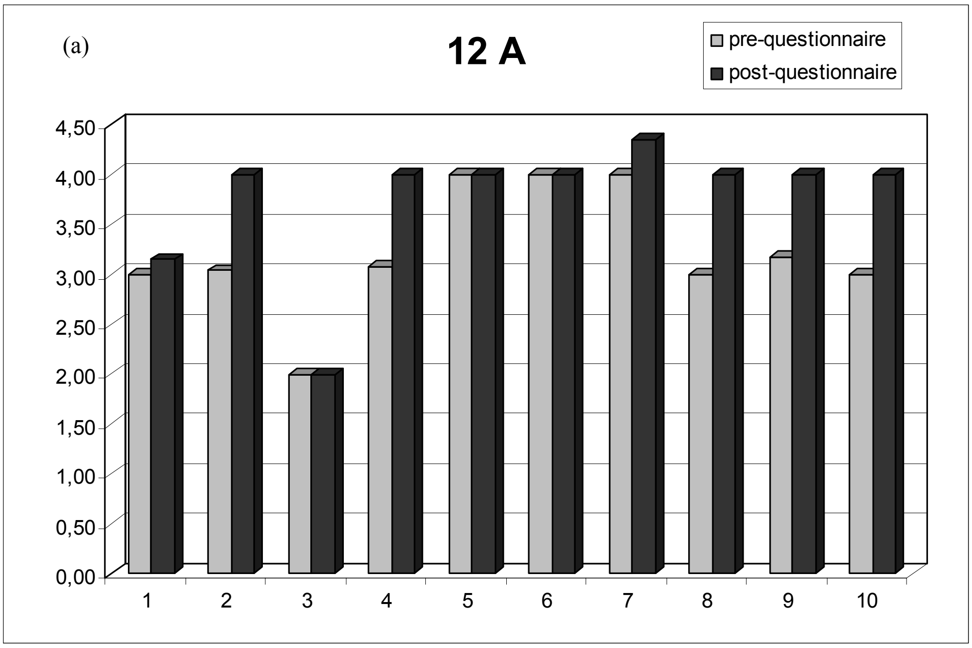


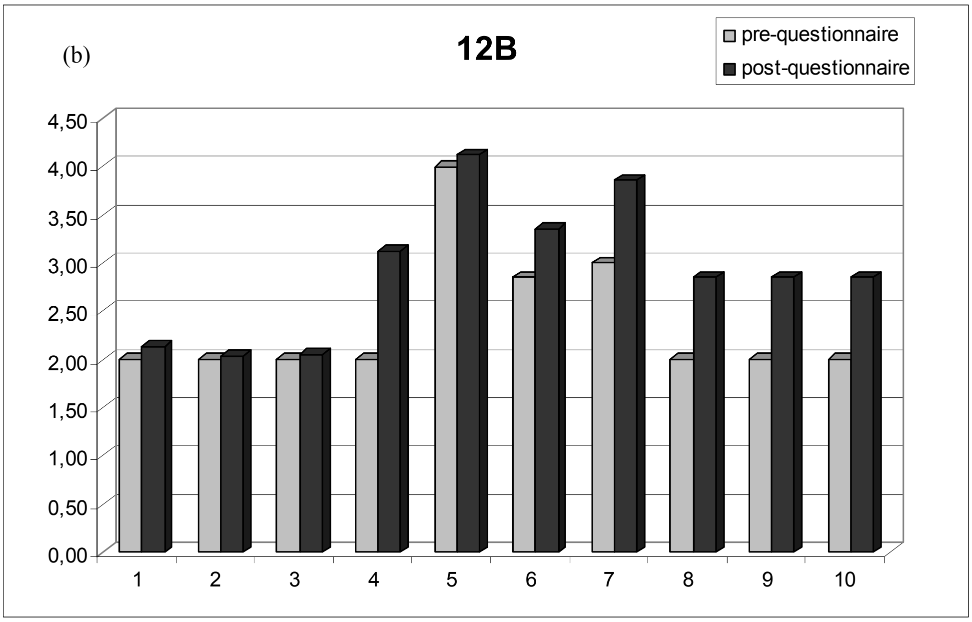

Fig. 12 – Discharges in low-pressurized tubes. The colored versions could be accessed at http://www.infim.ro/rrp/.

The first set of questions (1, 2, 3) referred to the Physics knowledge applicability after graduating, to their interest for this school subject, to the required amount of information. The second group of questions (4,5) requested opinions about the way Physics classes are attended, regarding the types of experiments and the strategies that were used. The next group of questions (6,7,8), referring to the didactical style, expected students' opinions about teacher's methods to make the class more dynamic, about the interaction between students, as well as the teacher's ways to encourage them to formulate questions and hypothesis. The last set of questions (9,10), requested marking the satisfaction level and emotional answer for the Physics classes.

The appreciation of the questions was made on a 5 rank scale, from 1 to 5, meaning from not at all to very much. The interpretation of the results showed problems that we expected: the lack of interest for the study of Physics along with the futility in real life of this knowledge and the great amount of information that is required to be learned. The students claim that they are not requested too much to be an active part during the class and this is what makes them not to have a constant interest for the lesson.

It seems that the organising and consecution methods of didactical activities are not made in a manner that would generate the interest of the students. This observation alerts that reconsidering the strategies we apply in the Physics classes is highly necessary because, under the circumstances, the classic approach do not





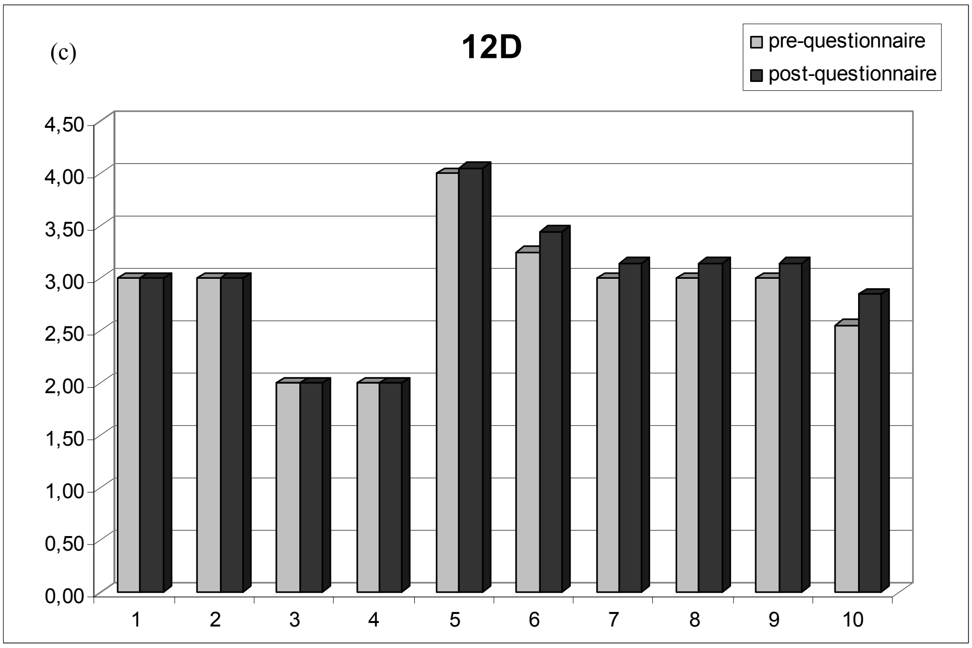




Fig. 13 – The registered results for the class 12A (a), 12B (b), and 12D(c).

satisfy the needs of our students. In this context we developed and tested new didactical strategies in a blended learning version, with their accent on virtual and real experiments, unfolded both in the High school's laboratory and at the Faculty of Physics. We hoped they will get the educational offer closer to the student's expectations, thus increasing the didactical efficiency and the quality of educational services.

The strategy used for the testifier-class 12D considers only some applets in both the expositive and experimental processes. The activities were preponderant classic and any real experimental activity has been suspended. They were presented only images, pictures and movies obtained in the laboratories mentioned above.

For the experimental classes, 12A and 12B, we used applets in the expositive sequences and in the experimental ones, along with a digital (with diffraction grid) and a prism spectrometers in the high school's laboratory. For the 12A class we chose the variant of having two classes of experimental work in the Atomic Physics Laboratory of the Physics Faculty, where they could work with different types of spectrometers. The results for the 80 students that participated to this study have demonstrated the efficiency of experimental work in real environment, even under the conditions of travelling from Drumul Taberei to Măgurele during winter. The post-questionnaires that were applied after the experimental activities, at the end of January 2011, contained the same groups of questions as the pre-questionnaires. A first analysis of the results shows a better correlation between the students' expectations and the educational activities held for the 12A class. These results are easily prefigured from the questionnaires.

For all the classes we can observe a strong utility of the virtual experiments – the average result was of almost 4 on the fifth question, which shows that pc and TIC usage does no longer minimize the gap between student's expectations and different educational offers. In exchange, the results that showed an evident increase on the fourth question, the real experiment test, were present only at the 12A and 12B classes, and it shows that this type of experiment could be the key to revive the interest of students in studying Physics. The increase is even stronger at the class that participated in activities in the Faculty lab. Here played a special role the novelty of moving to the Faculty lab as it broke the monotony of normal classes.

In the end, we take a look at the emotional profile of the students from the experimental classes as a result of their involvement into the lessons that implied blended learning strategies, dealing with a wide range of experiments in a real environment. A clear increase in the emotional answer of the students from the experimental classes has been noticed.

## 6. CONCLUSIONS

The results of our study show that the power of the experiment is the best choice for the student's interest in studying Physics revival, especially the real experiments, made individually or in small groups.

Our studies show that virtual experiments have their great role by that are not enough for illustrate the natural phenomena. In general, virtual physics experiment can be used as an alternative way of teaching and learning and make learning more fun and interesting. Students have demonstrated that they can learn both science content and laboratory skills in a virtual science laboratory environment. This viewpoint is provided using standardized tests and by questionnaires.

But the experiments conducted with real equipments in the laboratories show the secrets of the real world and remain the best ingredients for increasing the motivation for learning. As all the papers published in the Romanian Reports in Physics Journal, under the Educational Physics frame, [23-29], show that the experiment has the most important role in teaching and learning Physics today.

Students do not get developed through the experiments conducted in front of them but through those they made themselves [30].

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