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EMF IN EDUCATION: A TEACHING METHOD ALTERNATIVE TO FRONTAL LESSONS FOR SECONDARY SCHOOL STUDENTS

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Abstract:

EMF physics and bioelectromagnetism are not easy subjects to be understood and appreciated by secondary schools students and teachers in general face difficulties in finding the right teaching approach and building a real interest in the subject.
In this scenario, our work represents an attempt to develop a teaching method, alternative to standard class lectures, leading to the full comprehension of the subject and to the rising of a true interest in pupils. The proposed teaching strategies are based on ad hoc tools and a school contest. The tools have been designed as small exhibition stands where students can experiment, touch and collect information regarding EMF. Most of the tools are constantly exhibited in the Marconi Museum of Villa Griffone, in Pontecchio Marconi, but they have been projected to be easily portable for local interventions in schools.

Descriptions

In order to involve secondary schools students attention in electromagnetic fields related subjects, three ad hoc tools have been developed: a radiometer, a videogame, and a mobile measurements laboratory.
In addiction to this a thematic school contest have been organized to catch pupils interest, trough the competition, and to encourage active working group on a complex subject like EMF, combining fun with learning in a "out of classroom" situation.

The radiometer

Fig. 1- Radiometer

One of the most effective devices we realised is represented by a radiometer capable of detecting the electromagnetic emission of human body in RF range. Assuming that the human body emits like a grey body, the energy radiated in a specific frequency band can be easily derived by the Planck radiation law [1], [2].
In particular, assuming a temperature of 310 K and a frequency range up to 300 GHz (B=300 GHz), the human body emits a power density of 3 mW/m^2, which is slightly grater than the radiation emitted by the Earth (2.7 mW/m^2 for T=293 K and B=300 GHz).
Stemming from the former considerations, the radiometer as been realised using components familiar to students, such as common parabolic antenna for satellite program reception.

The antenna detects the weak emission coming from a person standing in front of the radiometer and, after a proper amplification, the signal is shown on a monitor as a peak appearing when the body moves within the antenna lobe. Obviously the signal level depends on the person's location in terms of distance, position with respect to the main antenna lobe and so forth.
Students passing in front of the radiometer are shown that the electromagnetic waves are not only the result of devices such as radiobase stations and cellular phones utilization, but human body emits electromagnetic waves in radiofrequency range too.

The videogame

In order to explain urban propagation and system coverage principles to young people, a videogame based on a sophisticated ray-tracing prediction tool has been realised. The scenario where the game takes place is a 2 km in side square typical central urban area, where 26 possible site locations are available for UMTS base stations.

Fig. 2 – Videogame

The player can choose a sub-set of the sites, for placing UMTS transmitters. For each positioned base station,the player can vary the emitted power over three levels (minimum, medium and maximum). Once chosen the sites, the player has on his disposal a total "amount of available power" to distribute, with the intent of realising a satisfactory system coverage for 90% of the urban area: the higher the number of BS, the lower the emitted power per station. Cover estimation is computed using a sophisticated ray-tracing tool. Thanks to the video game the student has the opportunity to get acquainted with the concept of system coverage and EMF propagation in urban areas.

The goal of the game cannot be reached simply by increasing the source number. By playing this game student can easily experience the concept of propagation and coverage and learn that the field strength level is not strictly related to the number of sources installed within the area under consideration.

The BlueShuttle vehicle

A quite innovative tool for electromagnetic field impact on environment and human health teaching is represented by the BluShuttle vehicle which consists of a city car equipped with a PMM8053 broadband EMF portable meter equipped with an EP330 probe [3], installed on the top. The probe is suited for measuring electric and magnetic field in the 100 kHz – 3 Ghz range.
In this way students can observe directly how an EMF measurement campaign is performed, see how the number on the instrument's display vary in presence or in absence of a cellular phone ringing near the probe, perform some measurements, learn the meaning of quantities like V/m, A/m and their difference, get in touch with the far field/near field concepts, ask questions to the technicians and receive high level scientific explanations; to summarize the car acts as a mobile conference site and an expertise laboratory at the same time. The tipical "BluShuttle Day" for a Secondary School is organized in the following way:

1) two hours of lectures on electromagnetic fields physics, biological effects of electromagnetic fields, national and international regulations and restrictions.
2) two hours of measurements with the car. During this "sperimental lessons" technicians face with students the following topics:

a. how an electromagnetic fields meter works;
b. what contains inside;
c. what is the meaning of the numbers resulting from the measurements;
d. how to compare result from measurements to limits and action values reported in regulations;
e. the difference between average electric or magnetic field values and peak values;
f. the meaning of far field or near field and the consequence for measuring activity;
g. how to perform a correct measure

To this follows a large number of measurements sessions involving students and teachers.

3) a final discussion where results of the measure campaign are presented and student can ask the technicians questions about the whole day activities.

If adequately prepared by the teachers before the meeting, BlueShuttle lessons can turn into a precious opportunity for student to face, at high scientific level, topics that, for their intrinsic difficulty, are not included in Secondary Schools educational programs.
This itinerating teaching formula, conveniently modified and adapted, can be applied to Primary Schools students too.

The Secondary School contest

The Secondary School contest have been projected in order to invite young people to reflect on the relationship between TLC technologies, environment and health; students are asked to realize projects based both on scientific and communicational approach.
The main title for the contest is "Electromagnetic Fields and Society", but the subtitle changes every year in order to let the students approach to the same topic from different points of view.
In six years of contest the following topics have been proposed:

1) Electromagnetic fields and society in general;
2) Electromagnetic field and society : techical and communicational considerations;
3) Electromagnetic fields: the scientific approach in communication;
4) Electromagnetic fields under a territorial point of view;
5) Professional exposure to electromagnetic fields;
6) Scientific information and communication.

Classes were asked to produce a working project; a first selection based on the project description was made by a first level jury composed by experts from science, communication and industry world.
Classes admitted to the second round of the competition were asked to produce a final work in one of the following forms:

- Full didactic dossier;
- Sintetic newspaper article;
- Detailed scientific article;
- Movie:
- Draft or website;
- Events and meetings

The final works proposed were submitted to a second level jury for an evaluation based on the following parameters:

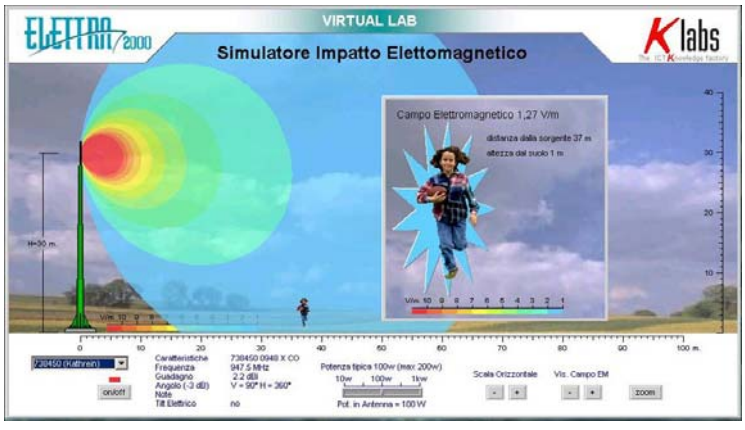
1) Relevance to the main contest topic;
2) Peculiarity;

3) Typology (original research or compilation)
4) Scientific level and critical skills emerged;
5) Documentaty modes;
6) Expressions used;
7) Multidisciplinary approach;
8) Communication effettiveness;
9) Approach with the territorial peculiarity;
10) Students mastery of the subject;
11) Collaborations between students, group of students or classes;
12) Autonomy of the research.

Winner projects were awarded during a commencement organized in form of a conferente in which students were asked to present their activities to an audience composed by their schoolmates and teachers, boys and girls from other classes or schools, scientists, communicators and a testimonial from the entertainment world.
During the commencement day students were given the opportunity to confront each other thank to the public presentation of their final projects, to attend a lecture on the main contest topic given by experts, to listen some advices provided by communicators or industrial managers, combining fun with new and useful knowledge acquisition.
The cash prize was 1500 euros for the first group listed, 1000 euros for the second and 500 for the third. Money were supplied directly to the school for books and teaching equipment purchase.

Other interactive tools

In addiction to the described tools and projects, in order to involve more students on electromagnetic fields topics, Elettra 2000 realised some specific lectures addressed to young people. To make the lectures more incisive and clear the arguments steam from day-life normal situations, to provide an example: during the lecture students can "watch" the radio. Thanks to a spectrum analyser, tuned on a chosen broadcasting radio program, the learners can listen to the music, while watching the transmitted radio wave shape on the spectrum analyser display.
This device can be used also for lessons dedicated to younger people, because the radio and the displayed waveform attracts childrens' attention leading to a series of interesting questions and considerations arising from pupils.



To make students more familiar with complex concepts such as electromagnetic waves transmission, propagation and signal reception, we have also implemented some Virtual Lab Modules (VLM) predicting the field strength level generated by a base station. The VLM has been realised in Java.
The students can vary different parameters:

Fig. 3 – Interactive virtual Lab

1) antenna model;
2) irradiated power;
3) antenna tilt;

4) distance of the observation point from the source

The simulator outputs the EMF prediction, represented in a color scale, so that the user can have an estimation on electromagnetic field exposure at the observation point and make, for instance, a comparison with limits and action values provided by law.

Discussion

Radiometer tools easily attracts students that can directly experience electromagnatic fields phenomenon. The possibility to see the radiofrequency signal emitted by a body leads them to ask questions about biological interactions involving radiofrequency field and organisms, allowing the teachers to introduce complicate subjects as thermal effects of EMF exposure and the notion of SAR – Specific Absorption Rate -, topics that may result useful in scientific texts on biolectromagnetism reading and comprehension.
Videogames represent of the most used entertainment tools for 14-18 years age groups. In this case our goal was to produce a didactic tool combining the attraction provided by a videogame with the opportunity to learn, trough direct visualization, concepts involving electromagnetic field propagation; a topic impossible to explain without falling into elevate difficulty level physics frontal lessons.
From our experience involving more than 50 classes every year, students enjoy the videogame and often they spontaneously organize groups for challenges in the research of the minimum power configuration. This leads them to start thinking in terms of output and coverage.
Both the radiometer and the videogame played a key role in catching students attention during educational visits at Villa Griffone; the feedback from teachers in general is positive, radiometer and videogame use has contributed in building an interest in students that went beyond the specific educational visit and allowed to deal with electromagnetic field issue from a solid starting point.

Fig. 4 – BluShuttle vehicle

For what concerns the BluShuttle vehicle, more tha 150 schools have been visited and more than 60.000 km have been travelled during the last 5 years of activity. The number of students and teacher involved is very high (about 5000 Secondary Schools students and more than 500 physics, mathematics and science teachers)

The BluShuttle, thank to the characteristic structure and the on board instrumentation, immediately capture students interest, leading them to try the tools and ask questions.

The presence of our technicians turns the meeting into an outdoor lesson on electromagnetic fields, measurement techniques, biological effect of non ionizing radiations. The feedback from teachers and students is positive.

The school contest have been organized for six years; about 120 classes, from all Italy and all kind of Secondary Schools have been participated. The presented works quality was substantially good; the scientific level was dependent to the topic proposed in the contest subtitle.
Best results were achieved in technical and scientific contest editions, while many difficulties have been experienced in dealing with communication related issues. This is most likely due to the Italian school formative offering, which is focused more on technical aspects than communication modes and formal aspects.

In general, the most popular final work presentation was the detailed technical dossier, which represent the kind of presentation mostly used in Secondary Schools. However, there have been also movies, projected and performed with passion (and fun) by students and teachers during after-school voluntary afternoons, drawings, meetings organized in order to present the activities carried out and the related results to schoolmates, teachers, parents within school headquarters or in locals provided by Local Administrators. During those events student present their activities in form of scientific meeting or round table, including a discussion part where they provide answers to participant's questions using their own knowledge about electromagnetic fields or supported by their teachers and, where required by the Elettra 2000 Consortium technicians.

Conclusions

The electromagnetic fields physics, the way electromagnetic fields interact with biological tissues and the potential health effects, for their intrinsic difficulty, are not included in Secondary Schools educational programs. EMF related topics are not easy to be taught to secondary schools students that in general do not own an appropriate scientific background and have not a specific interest in such a complicated subject.
These subjects, if not addressed during Secondary School, a will never be treated by the students, except by those choosing a scientific universitary curriculum enrolling in faculties like physics and engineering.
The main goal of our activity with schools was to concentrate students attention and interests in the specific subject and to give teachers some didactic tools, alternative to frontal lessons to easily face the topic.
The presented innovative tools and the dedicated school contest have been very helpful to teachers in approaching and introducing EMF physics and related biological effects to 14-18 years old people.

Specific tools as the radiometer for his specificity, the videogame and the virtual laboratory for being part of everyday teenager life, can easily capture students' interest, acting as a start up and making it possible to pursue the electromagnetic fields topic during standard frontal lessons in classroom, without any resistance from the students.
The BluShuttle vehicle represents a first hand laboratory experience, very useful in a school system where the hours and the structures dedicated to research and laboratory activities are extremely limited.
The Secondary School contest instead opens the way, through the natural young people competitiveness, to a formative training program carried out for and entire school year as preliminary preparation for the contest. The presentation on a project for the contest requires pre-targeted lectures performed by teachers, specific bibliotecary or interactive research activity and group working that often are carried out on a spontaneous students request, spurred by the desire to excel in the competition. All those necessary activities are performed during after school time, leading to an educational program voluntary enrichment and to the stimulus for teachers and students to work together as a team on a project.

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