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**Education in nuclear science at IPEN/CNEN, São Paulo, Brazil:**

**Advanced School of Nuclear Energy – EAEN.**

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**Abstract**

EAEN<sup>(1)</sup> (Advanced School of Nuclear Energy) is an annual school that consists of a week of activities in the area of Nuclear Physics, Radiochemistry and uses of Nuclear Energy for a public composed of *high school students*. The EAEN project represents a pioneering program on science education and dissemination of knowledge, conducted by researchers and focused mainly on *high school* and scientific education in the general population. The school's priority is to explore the failures and lack of education in dissemination of nuclear energy for *high school students* as well as to attract prospective students with great potential for postgraduate (Renato: eu acho que normalmente eles chamam cursos de pós-graduação de graduate courses) courses of IPEN and other institutions in Sao Paulo and in Brazil.

**Keywords:** Education in nuclear science, Educational methods, Applications of the nuclear energy.

**Introduction**

Brazil belongs to the group of countries with nuclear technology: 1) it has electricity produced by nuclear power plants (Angra 1 and Angra2) and will continue to use nuclear energy in its electrical matrix<sup>(2)</sup> (there is also the possibility of building other nuclear power reactors in the future), 2) it has four research reactors and the Science and Technology Ministry has decided to support the new research reactor (Brazilian Multipurpose

Research Reactor – RMB) construction in accordance to the Brazilian Nuclear Program<sup>(2)</sup>. The RMB will produce radioisotopes for application in health and industry, it will conduct testing of nuclear fuels and structural materials for nuclear reactors of nuclear power plants and strategic projects for the country, it will provide neutron beam to scientific and technological studies, and it will form human resources to meet the needs of the Brazilian Nuclear Program, 3) Brazil also dominates the fuel cycle technology, including uranium enrichment, and has a significant uranium ore reserve<sup>(2)</sup>, 4) Brazil has cyclotrons in operation for radioisotope production aiming at nuclear medicine and also **possesses** electron accelerators for research and for medical and industrial applications.

It is more than evident, further with increase of nuclear techniques applications and radioisotope utilization in the benefit of the society in Brazil, the need to continue the training of human resources, **by** specialists, scientists and teachers in nuclear physics, radiochemistry and reactor physics.

There is no denying that, almost every day, the media bring us some information on topics related to nuclear energy. Most of these topics are not disseminated to the *high school students* in Brazil. The beneficial applications of nuclear energy are little known by those students, except the part involved with power generation. Most of these students still have a distorted view of the applications of nuclear energy and exclusively **related** to weapons and radioactive accidents. In Brazil, only topics on radioactive decay are introduced at the high school. Nuclear and radiochemistry programmes are offered in undergraduate and graduate courses<sup>(3)</sup>. Thus, it is essential to design and **implement a school** that explores the lack and failures of education in the nuclear area in *high school*. **It should be a high level school, up-to date**, with annual occurrence, that **covers** the deficiencies observed in the preparation of high school students to the international Chemistry and Physics Olympiads<sup>(4,5)</sup>, a school with experienced teachers and researchers in the nuclear area and education, a school that has the purpose of dissemination of the many applications of nuclear energy for the benefit of society.

IPEN / CNEN – SP is the largest nuclear institute in Brazil and it is located in the campus of the University of São Paulo (USP), occupying an area of about 500,000 m<sup>2</sup>, with 20% of constructed area<sup>(3)</sup>. The Institute plays a very important role in nuclear science and technology in Brazil, being recognized as a national leader in the generation of knowledge in this field. It runs the 5MW IEA-R1 nuclear research reactor, a Van de Graaf accelerator, two electron accelerators of 1,5 MeV, two cyclotrons for radioisotope production, activities of teaching (nuclear technology graduate course) and research in nuclear and radiochemistry<sup>(3)</sup>. There is no doubt

that IPEN is the appropriate place for realization of Advanced School of Nuclear Energy for *High School: Theory and Applications of Nuclear Sciences*.

### **Advanced School of Nuclear Energy for *High School: Theory and Applications of Nuclear Sciences*.**

The Advanced School of Nuclear Energy is an annual school that consists of a week of activities in the area of Nuclear Physics, Radiochemistry and uses of Nuclear Energy for a public composed of *high school students*. The I EAEN happened in June, 2008 at IPEN. One hundred and fifty students participated in the first edition, from which 40 were selected. Due to the success of the first edition, **continuity was given to the project** with the II EAEN (2009) and III EAEN (2010). At the end of 2011 June , **the IV EAEN will be held** at IPEN.

Among the main objectives of EAEN the following are highlighted: publicizing the beneficial applications of nuclear energy at *high school*; stimulate *high school students'* interest for Physics and Chemistry through several theoretical and practical activities of Nuclear Physics, Radiochemistry and uses of Nuclear Energy, which are normally not part of the high school content; to provide *high school students* (with scientific aptitudes) the opportunity of direct contact with working scientists from one of the biggest research centers in the Nuclear segment in Latin America through the carried out activities; to show the students how the content of Chemistry and Physics at *high school* can be applied in research in the Nuclear segment; advertise the importance of scientific activity and its insertion in modern life; to promote the didactic capacity of the teachers from the several IPEN centers through activities related to high school students; to contribute with community service; advertise the IPEN institution at high school; to enable *high school students* to participate in the several national and international Physics and Chemistry Olympiads; acknowledge the creative potential of the youth as its most valuable asset; to understand education as the cornerstone of the development of citizens and the Nation; to incentivate practices of citizenship, ethics and social responsibility; to act with honesty in actions and purposes; to value group work.

The activities **are** held from Monday to Saturday, from 8:00 am to 6:00 pm with intervals for coffee and lunch. The course consists of introduction to nuclear physics theoretical lectures, lectures on the beneficial applications of nuclear energy, discussion on the problem of radioactive waste, advantages and disadvantages of using nuclear energy, special lessons about olympic( Renato: não entendi isto) problems involving nuclear chemistry and nuclear physics, simulations, demonstrations, exhibition of IPEN advertisement material and occasional visits to the main IPEN laboratories, to the IEA-R1 research reactor, radioisotopes production center, industrial

electron accelerator and Cobalt-60 multipurpose irradiator. The course had the orientation of a supervisor of radiological protection, which was part of the teaching staff.

The working team consisted of 36 teachers, being IPEN researchers and visiting professors from other institutions: Institute of Physics at the University of Sao Paulo – IFUSP, Federal University of Sao Paulo – UNIFESP, Institute for Advanced Studies – São Jose dos Campos – IEaV , Oceanographic Institute of the University of Sao Paulo – IOUSP, Navy Technology Center in Sao Paulo – CTMSP, ETAPA Education and Culture e School of Engineering and Management – ESEG.

The EAEN program is divided into three areas:

**1. Introduction to Nuclear Physics:** Renato: Talvez fosse melhor itemizar esses tópicos, o que você acha?)

Lectures on the following topics: Atoms and nuclei, radioactivity, interaction of radiation with matter, nuclear reactions, fission and fusion, nuclear astrophysics, nucleosynthesis and astrophysical environments, introduction to neutron physics, neutron diffraction and applications, angular momentum and nuclear models, nuclear detector, nuclear instrumentation, basics of radiological protection, scientific computing in nuclear physics, radioactive wastes, IEA-R1 research reactor, RMB - The Brazilian Multipurpose Reactor, Nuclear power reactors, basics of measures and errors in experimental nuclear physics, environmental radioactivity, biological effects of radiation, history of nuclear energy in Brazil.

**2. Applications of Nuclear Energy:**

Lectures on the following topics: Neutron activation analysis and applications, BNCT – Boron Neutron Capture Therapy, doping of monocrystalline silicon with phosphorus using the technique of nuclear transmutation, application of radioisotopes in health, intense sources of ionizing radiation, food irradiation, detection of irradiated food, radiosterilizing products, modification of polymers by radiation, production and applications of radioisotopes, applications of nuclear energy in the environment, industry, agriculture, medicine.

**3. Training for IPhO e IChO (optional)** - Special lessons about Olympic (?) problems involving nuclear chemistry and nuclear physics for selected students to the International Olympiads in Physics (IPhO)<sup>(4)</sup> and Chemistry (IChO)<sup>(5)</sup>.

## Conclusions

An evaluation of EAEN made by students during the last day of class (Renato: talvez fosse bom colocar um pouco mais de detalhes de como foi essa avaliação) , showed that the realization of EAEN was a success and reached almost all the proposed objectives. There was a great effort, not only by the coordination, but by

teachers, companies and institutes that have supported us for the realization of the school. The school explored the lack and failures in education in the nuclear area in *high school*. The classes were didactics and high-level, compatible with the profile of the selected students. Despite the short duration, we believe that the school met the expectations of students and contributed to minimize the deficiencies observed in the preparation of *high school students* for international olympiads. Renato: o que você acha de colocar o número total de alunos que frequentaram as tres escolas ? Talvez pudesse mencionar também que vieram alunos de outras partes do Brasil. ?The school had experienced teachers and researchers in the nuclear area and education, and had, as one of the main purposes, the dissemination of numerous applications of nuclear energy for the benefit of society (which usually has a distorted view and related to explosives and harms). The EAEN is a way to disseminate nuclear energy for *High School*. We believe that the EAEN project represents an ambitious program of science education and dissemination of knowledge, conducted by researchers and focused mainly on *high school* and in the general population scientific education. The realization of EAEN is annual and we are already working in the organization of IV EAEN, to be held in June 2011 at IPEN.

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