

Education in nuclear science at IPEN - CNEN, São Paulo, Brazil: Advanced School of Nuclear Energy—EAEN

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Received: 23 May 2011 / Published online: 5 June 2011
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Abstract EAEN (Advanced School of Nuclear Energy, 2010) 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 made 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 for the population in general. The school's priority is to explore the failures and the lack of education in the dissemination of nuclear energy for *high school* students as well as to attract prospective students with great potential for graduate 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 Angra 2) and will continue to use nuclear energy in its electrical matrix [1] (there is also the possibility of building other nuclear power reactors in the future), (2) Brazil has four research reactors and the

Ministry of Science and Technology has decided to support the construction of the new research reactor (Brazilian Multipurpose Research Reactor—RMB), in accordance to the Brazilian Nuclear Program [1]. The RMB will produce radioisotopes for application in health and industry, conduct the testing of nuclear fuels and structural materials for nuclear reactors of nuclear power plants and strategic projects for the country, provide neutron beams to scientific and technological studies, and also capacitate 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 [1], (4) Brazil has cyclotrons in operation for radioisotope production aiming the nuclear medicine and also possesses electron accelerators for research, medical and industrial applications.

Taking into account the increase of applications of nuclear techniques and the use of radionuclides for the benefit of the society in Brazil, it is necessary to continue the training of human resources by specialists, scientists and teachers in nuclear physics, radiochemistry and reactor physics.

It is impossible not to perceive that, almost daily, the media bring us information on topics related to nuclear energy. Most of these topics are not discussed among *high school* students in Brazil. The beneficial applications of nuclear energy are not well known by those students, except the part which involves power generation. Most of these students still have a distorted view of the applications of nuclear energy, relating it exclusively to weapons and radioactive accidents. In Brazil, only topics about radioactive decay are introduced during *high school*. Nuclear and radiochemistry programmes are offered in undergraduate and graduate courses [2]. Thus, it is essential to design and implement a school that explores the lack and failures

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of *high school* education in the nuclear area. It should be an updated high level school, with annual occurrence, that covers the deficiencies observed in the preparation of *high school* students for the international Chemistry and Physics Olympiads [3, 4], a school with experienced teachers and researchers in the nuclear area and in the field of education, that has also 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 m², with 20% of constructed area [2]. 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 5 MW IEA-R1 nuclear research reactor, a Van de Graaf accelerator, two electron accelerators of 1.5 MeV, two cyclotrons for radioisotope production, teaching activities (nuclear technology graduate course) and research in nuclear and radiochemistry [2]. There is no doubt that IPEN is the appropriate place for the implementation of the 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 [5] 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 took place 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 June 2011, 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*; stimulating the interest in 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. EAEN also aims 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; to 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; to 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 breaks for coffee and lunch. The EAEN program is divided into three areas (see Table 1) and the course consists in the introduction of nuclear physics theoretical lectures, lectures on the beneficial applications of nuclear energy, discussion of the problem of radioactive waste, advantages and disadvantages of the use of nuclear energy, special lessons about problems related to international Physics and Chemistry Olympiads 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, to the radioisotopes production center, to the 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 and School of Engineering and Management—ESEG.

Conclusions

An evaluation of EAEN was made through a questionnaire answered by students during the last day of class. This evaluation showed that the implementation of EAEN was very successful and met almost all the proposed objectives. There was a great effort, not only by the coordination, but by the 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 high-level classes were didactic, compatible with the profile of the selected students. Despite its short duration, we believe that the school met the expectations of students and contributed to minimize the

Table 1 The EAEN program

Area	Topics	Classes ^a
Introduction to nuclear physics	Atoms and nuclei	2
	Radioactivity	2
	Interaction of radiation with matter	2
	Nuclear reactions	1
	Nuclear astrophysics, nucleosynthesis and astrophysical environments	2
	Introduction to neutron physics	3
	Neutron diffraction and applications	1
	Angular momentum and nuclear models	3
	Nuclear detectors	2
	Nuclear instrumentation	1
	Basics of radiological protection	2
	Scientific computing in nuclear physics	1
	Radioactive wastes	2
	IEA-R1 nuclear research reactor (visit included)	4
	RMB—The Brazilian multipurpose reactor	2
	Nuclear power reactors	3
	Basics of measures and errors in experimental nuclear physics	2
	Environmental radioactivity	1
	Biological effects of radiation	2
	History of nuclear energy in Brazil	2
Applications of nuclear energy	Neutron activation analysis and applications	1
	BNCT—Boron neutron capture therapy	1
	Doping of monocrystalline silicon with phosphorus using the technique of nuclear transmutation	1
	Application of radioisotopes in health ^b	3
	Intense sources of ionizing radiation ^c	4
	Food irradiation	1
	Detection of irradiated food	1
	Radiosterilizing products	1
	Modification of polymers by radiation	1
	Production of radioisotopes	1
Training for IPhO and IChO (optional)	Applications of nuclear energy in the environment, industry, agriculture	1
	Applications of nuclear energy in the nuclear medicine	1
	Special lessons about problems involving nuclear chemistry and nuclear physics for selected students to the International Olympiads in Physics (IPhO) [3] and Chemistry (IChO) [4]	4

^a The duration of a class is 45 min

^b Lecture and visit to the radioisotopes production center

^c Lecture and visit to the industrial electron accelerator and Cobalt-60 multipurpose irradiator

deficiencies observed in the preparation of *high school* students for international olympiads. The total number of students that participated in the three schools performed so far is 120. Students from other cities and states (Goiânia—GO, Minas Gerais—MG, Paraíba—PB and Paraná—PR) participated in previous schools. 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 (that usually has a distorted view, relating it to explosives and damages). The EAEN is a way

to spread the topic nuclear energy at *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 from 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.

Acknowledgments The authors would like to acknowledge to all teachers who contributed to the success of this school due to the effort

and dedication, as well as for those who have offered support: Instituto de Pesquisas Energéticas e Nucleares—IPEN - CNEN / SP, ETAPA Educational Group, Brazilian Nuclear Energy Association—ABEN, Eletronuclear and Navy Technology Center in Sao Paulo—CTMSP.

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