

NUCLEAR SCIENCE COMMUNICATION: EDUCATING EDUCATORS, CHILDREN AND TEENAGERS

Levy, D.¹, Khoury, H.J.²

¹ Omicron P.G., Brazil

² Museu de Ciências Nucleares da Universidade Federal de Pernambuco, Brazil

ABSTRACT

Nuclear science is not usually part of the Brazilian scholar curriculum and is still a controversial issue among a large fraction of the population. Scientific communication is a big challenge. The Educational Portal Radioatividades and the Nuclear Science Museum are Brazilian initiatives that work on nuclear scientific divulgation for students, teachers and the general public. This article discusses some actions focused on science communication events, such as national thematic weeks, to enhance the public's understanding of nuclear science. Providing accessible scientific information, according to the several week themes, it is possible to develop different strategies to present nuclear science in an interesting and meaningful way. In 2016, during the National Museums Week, under the theme "Cultural Landmarks", there was developed a range of activities linking world's famous landmarks to nuclear science, such as: radiocarbon dating process in Egypt, nuclear power generation in Paris, natural occurring radiation in Brazil, radiography of paintings in Florence, among others. Teaching science-related themes in non-school contexts are opportunities to explain concepts and engage children and teachers in scientific issues. Teaching strategies focus on meaningful learning premises: (1) to consider prior knowledge and its impacts on self-motivation learning process and (2) to facilitate meaningful connections between new information and everyday life. Moreover, besides the thematic science weeks, both initiatives, the Educational Portal and Nuclear Science Museum work on complementary and diversified information all year long, which includes expositions, interactive material, workshops and lectures for students and teachers. Nuclear science affects us all, in more ways that the public realizes, from our everyday lives to global issues: food, energy, agriculture, health treatments, and industrial applications. As citizens, people need to form opinions, evaluating media communications, making informed decisions, participating in debates and popular consultations. It is expected that these initiatives improve public's acceptance of nuclear science, stimulating curiosity and encouraging research.

1. INTRODUCTION

Nuclear science is still a controversial issue and most often misunderstood among a great fraction of the Brazilian population. Even though the national Brazilian curriculum contemplates nuclear physics in Fundamental and High School, it is often a small part of physics education and not explored as deeply as it should, considering the impact of the beneficial applications of nuclear sciences in our everyday-lives. According to the Brazilian Law of Guidelines and Bases for National Education (1996) [1] and to the National Curricular Guidelines for Basic Education (2013) [2], schools are responsible for providing the minimum curriculum to students to allow the development of skills and competencies for a fair comprehension about nuclear reactions and their applications. Nevertheless, teachers themselves are also most often unaware of the issue and not prepared to discuss it deeply. Focusing exclusively on minimum formal curriculum, schools seem to transmit the issue at a superficial level, not addressing the critical thinking needed to prepare students to further

¹ E-mail del primer autor: denise@omicron.com.br

researches or to discuss actual issues involving nuclear technology [3]. On the other hand, nuclear technology has developed rapidly and has been improving our lifestyle in issues that touch each and every one of Brazilian population, such as: food safety, agriculture, nuclear medicine and industrial applications. The fact that nuclear science classes stay at a superficial level has bad consequences: unfounded prejudices and misinformation lead the public to associate nuclear techniques to major accidents, mass destruction weapons, harmful effects to human health or environment contamination. New generations are expected to take part in decision making processes pertaining to our society [4]. With only a superficial knowledge among a wide range of applications, how will the new generations discuss the construction of new research reactors, their purchase intention of irradiated food or whether they favor nuclear energy? Scientific divulgation is a must and this paper discusses attitudes to improve communication, demystifying paradigms, fighting misinformation and combating about nuclear sciences. The main objective of this paper is to answer to the question: what can the scientific community do to include nuclear science education between the expected school curriculum and the expected knowledge in a citizen's life? This paper discusses two initiatives to support the school goals to reach the National Curricular Guidelines, providing students non-formal learning environments that reinforce the formal curriculum.

A deeper learning of nuclear physics has some specific requirements, such as multidisciplinary approach, articulating Physics with Chemistry, Geography, History, Biology and Mathematics. Educators are expected to offer new dimensions of nuclear physics, articulating science to students' previous experiences, promoting contextualized knowledge, making science meaningful and relevant. Risk perception and risk acceptance are a matter of education [5]. It is a must to regard issues in a social context, such as nuclear energy in a social scale, including its risks and benefits; such as food irradiation in a social scale, when comparing to other preservation techniques and taking into account that food supply is one of the most important issues in our country; such as the fight against mosquito-borne diseases like *Aedes aegypti*, a well-known vector of several viruses including chikungunya, zika and yellow fever, as well as dengue, which is a big concern in Brazil! It is essential to consider the life experience of the students, meaningful experiences with which they effectively deal, and the issues that instigate their curiosity.

2. METHODOLOGY

Non-formal education environments can be seen as learning actions to develop capacities beyond formal school curriculum, improving interdisciplinary competences related to social contexts and lifelong learning.

The Nuclear Energy Museum of the Federal University of Pernambuco is located in Northeast region in Brazil. It is the first and the only museum entirely dedicated to communicating the beneficial applications of nuclear sciences in our country. The museum offers a full learning program through mediated experiences, exhibits, interactive displays, as well as interactive learning material, inviting visitors to play an active role in their learning processes.

Educational Portal Radioatividades (Radioactivities) is a web-based learning environment designed to encourage teachers and students from all over Brazil to enrich their knowledge about nuclear sciences. Multimedia is one of the powerful tools to spread knowledge to

distant geographic areas, overcoming distance barriers in Brazil, providing members of society with an empowering learning environment with high quantity and quality of scientific-based material.

One of the most interesting ways to learn science is to relate it to everyday-life. And one of the most interesting ways to teach science is to relate it to meaningful social contexts, which is the purpose of scientific thematic weeks: the (re)organization of formal curriculum around a central theme, which is presented by several institutions, under different points of views, promoting interdisciplinarity and meaningful contextualized scientific approaches all over the country. Therefore, taking advantage of scientific thematic weeks, these two initiatives – the Nuclear Energy Museum and Educational Portal Radioatividades – promote every year partnership action plans to offer the public new perspectives of nuclear science. Learning actions include: lecture for high-school students and teachers, workshops for science teachers and original interactive material, according to each thematic week.

3. RESULTS AND DISCUSSION

All learning solutions were developed to act as alternative routes to complementary scientific education improving the public's skills and competencies to understand radioactivity, natural phenomena and technological systems, nuclear reactions and their applications in nuclear power plants, industry, agriculture and medicine. Taking advantage of the several Brazilian thematic weeks, there were developed the following educational solutions:

- 2014 – during the National Museum Week: workshops for science teachers and lectures for teachers and students.
- 2015 – during the Museum Spring Week: mediated exhibitions for the general public in one of the greatest shopping malls in Recife City.
- 2016 – during the National Museum Week: interactive activities and lectures about the several beneficial applications of nuclear sciences.
- 2017 – during the National Week for Technology and Science: interactive games focusing interdisciplinarity and new approaches between nuclear science and math.

All teaching strategies for these learning actions were focused on fundamental learning premises:

- to consider prior knowledge and its impacts on self-motivation learning process
- to facilitate meaningful connections between new information and everyday life
- to lead the learner through a real active participation in his learning process

In this session, we describe general learning activities promoted all year long, as well as specific learning actions developed in special thematic weeks in Brazil.

3.1. Improving teachers' knowledge level: teaching teachers how to teach

Natural and artificial ionizing radiations are part of our everyday-life, improving our lifestyle. Nuclear technology impact on social, political and economic contexts. Nevertheless, ionizing radiation is most often feared and associated to harmful effects to humans' health and to the environment. Taking into account that in Brazil nuclear science is not part of the school curriculum and that teachers themselves are not informed enough to discuss the issue in class,

both initiatives, the website Radioatividades and The Nuclear Energy Museum provide pedagogical support for teachers.

Educational Portal Radioatividades offers a special restricted area for teachers, with an “Ideas Bank”, which counts on Power Point presentations, games and ludic activities, as well as reliable further references for teachers to improve their knowledge about nuclear sciences. Teachers are given information presenting ionizing radiations into social, political and economic contexts. A representative example is food irradiation. Food chain supply is a major concern in Brazil [6] and food irradiation is one of the techniques that bring great contributions. Nevertheless, a great fraction of the population is unaware of this technique and most often do not know the difference between “food irradiation” and “food contamination”. For this purpose, teachers are given different games to teach and discuss food irradiation in a playful and interesting way (see Figure 1). Throughout the games, teachers can understand the process and the purposes of food irradiation and present its contributions to:

- human’s health (improving food safety),
- social issues (extending shelf-life and avoiding losses),
- country's economy (standards for exporting food).

INÍCIO	1	AVANCE 1 CASA	ALIMENTO IRRADIADO FICA RADIOATIVO? POR QUE?		DIGA 3 ALIMENTOS QUE NÃO PODEM SER IRRADIADOS		PASSE A VEZ PARA OUTRO GRUPO		DIGA 3 BENEFÍCIOS DA IRRADIAÇÃO DE ALIMENTOS
MANTEIGA PODE SER IRRADIADA? POR QUE?	 <p>TABULEIRO DOS ALIMENTOS PORTAL EDUCACIONAL RADIOATIVIDADES WWW.RADIOATIVIDADES.COM.BR</p>								VOLTE 2 CASAS
VOLTE 2 CASAS									POR QUE AS CEBOLAS SÃO IRRADIADAS?
DIGA 3 VANTAGENS DE IRRADIAR OS ALIMENTOS JÁ EMBALADOS									
									PASSE A VEZ PARA OUTRO GRUPO

Figure 1. Ideas Bank: supplementary teaching material to be developed in class.

Sensitive to the need of improving teachers’ knowledge, the Nuclear Energy Museum offers refreshing courses for science teachers of Fundamental and High School. In 2014 17 teachers attended a one-week-course entitled “Playing with the atom”. In 2016 science teachers from the state of Pernambuco were invited to the refreshing course named: “Refreshing course to school science teachers”, covering essential concepts related to the atom, radioactivity,

interactions of ionizing radiation, radiation applications (in medicine, industry, food and power generation) and biological effects of ionizing radiation. In addition, the museum teaches teachers how to teach nuclear science in a meaningful and interesting way.

Beyond these actions, every year, during thematic weeks, researchers and experts from both initiatives unify their efforts to develop creative learning solutions to present radioactivity. During the VIII Spring Museum Week in year 2014 there were developed a range of interactive material presenting several basic aspects of radioactivity in daily lives, in addition to lectures for the general public, as well as workshops for science teachers. During the workshops entitled “Educational technology as an engine for knowledge” and “Ludic experiences to build scientific knowledge”, teachers experienced themselves inductive inquiry-based science education, discussing their prior knowledge, building hypothesis, investigating myths and truths related to the phenomenon of radioactivity.

3.2. A deeper understanding of nuclear science

Science literacy is a must and it is possible since early childhood education. It includes the possibility of understanding and articulating science to daily-life contexts, developing the learners' ability to collect information, ask questions, (re)build ideas, and apply knowledge all lifelong [7]. Nuclear Power Generation is one of the current issues that divides public's opinion in Brazil. Nevertheless, people do not have enough information to discuss the issue.

How can non-formal learning spaces contribute to promote science literacy? All year long, the website RadioAtividades (RadioActivities) provides trustworthy information, focusing on current issues, as well as interesting themes which can be discussed at school. All year long, the Nuclear Energy Museum offers permanent exhibitions for students and teachers to enhance their knowledge about the beneficial applications of nuclear technology.

The website Radioatividades offers plenty of resources and ideas to be used in classroom. In order to enhance teachers' knowledge about nuclear generation the “Ideas Bank” presents the topic “Nuclear Energy is so cool!”. This item offers a Power Point presentation, supplementary material for teachers and a competition game about nuclear energy, to be easily developed in class. The topic discusses the most frequently doubts, such as: (1) Is it true that nuclear power plants use river or ocean water to cool the system? (2) How does the cooling water system work? (3) What happens to the hot radioactive water? (4) Is the radioactive water dismissed in the environment? (5) Is the process environmentally safe?

From January to December, the Nuclear Energy Museum promotes a social learning space dedicated to teaching nuclear technology applications. In this context, nuclear power generation is introduced through interactive activities, models and panels. Teachers and students are given explanations about the fuel cycle and learn that a piece of 3.0g uranium enriched to around 3.5% equals the energy generated by 1 ton of charcoal. Also, visitors are invited to find out about the operation of a nuclear reactor through an interactive panel visualizing the containment structure, control rods, steam generator, steam line and the cooling water condenser, among others. Examples can be seen in Figure 2.

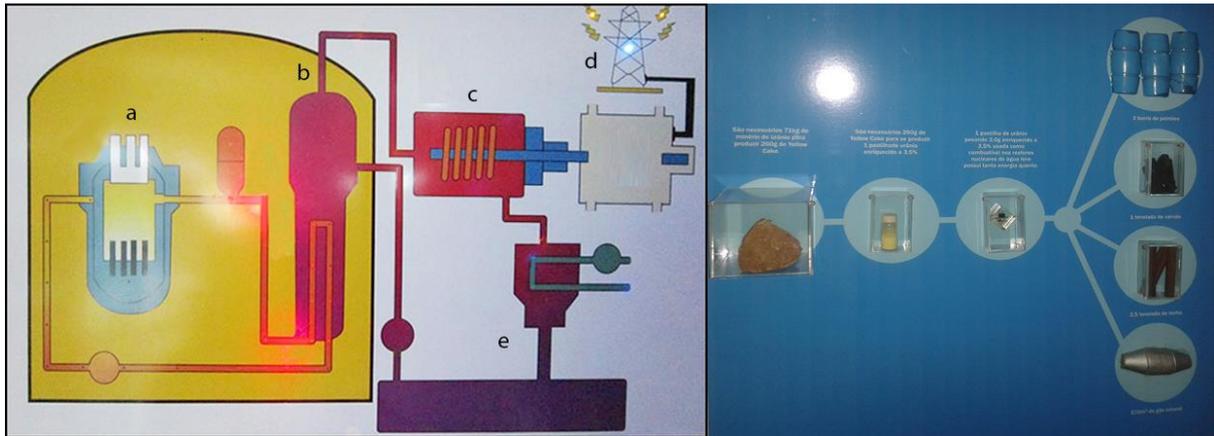


Figure 2. Illustrated and interactive panels to demonstrate the fuel cycle and the nuclear power reactors.

In addition to the permanent learning programs, available all year long, during thematic weeks further actions are considered. One expressive example occurred during the National Museum Week in Brazil, in May 2016. Under the theme “Natural Landmarks” hundreds of museums throughout Brazil prepared itinerant exhibits and special programs for this special week. How to relate nuclear power generation to the theme? Under the title “the radiations secrets behind the most beautiful cultural landmarks” the Nuclear Energy Museum, together with the expert team of the Portal Radioatividades has developed a range of interactive activities for students and teachers to explore the different aspects of radiations, among them:

- Paris, in France, and the role of nuclear power generation to illuminate Paris, “The City of Light”.
- Rio de Janeiro, in Brazil, the most popular touristic destination in Southern Brazil and also the only Brazilian state that produces nuclear energy.

Other than these two famous landmarks, visitors were introduced to natural radiation occurrence in New York, cosmic radiation in La Paz, X-Raying art works in Florence and Carbon-14 for archeological dating process in Egypt, among others. The virtual visit to these historical landmarks was a rich pedagogical tool that, in addition to being pleasant, helped in the process of understanding some great beneficial applications of nuclear science (see Fig.3).



Figure 3. Interactive activities: radiations secrets behind the most beautiful cultural landmarks

3.3. Developing critical thinking skills through education

Nuclear medicine helps to improve human's health, saving lives every day. Nevertheless, the general public, including parents and teachers, do not know all the implications of this process. Even though they claim to favor nuclear medicine, experience shows that they may be against the construction of new research reactors or the transportation of medical radioactive material in regular airplanes. If citizens take part of the making decision processes in our society, it is necessary to offer them reliable information.

In this sense, the website Radioatividades invite learners to consider about practical issues that concern their own lives. A very representative example is the construction of the Brazilian Multi Proposal Reactor, which has caused reluctance of environmentalists and unfounded fear of the local population. In this sense, the "Ideas Bank" for teachers website offers newspaper articles and further explanation about the purpose of nuclear research reactors, the importance of nuclear medicine for the diagnosis and therapy of various diseases and the need to increase the domestic production of radiopharmaceuticals.

At the Nuclear Energy Museum, the issue is discussed as well. Through panels, models and various objects, visitors are introduced to the production, transport and the several applications of the ionizing radiation for nuclear medicine. Moreover, making use of an interactive panel, students and teachers learn about the various radiopharmaceuticals and its applications in different parts of the body for diagnosis and treatment of several diseases.

The issue was also presented during a thematic week in September 2015, during the Museum Spring Week. Parents are educators, as well, and most often usually do not have much knowledge about nuclear technology applications. For this reason, the Nuclear Energy Museum proposed exhibitions for the general public in one of the greatest shopping malls in Recife City. The exhibition counted on the whole collection of the Museum and interactive activities specially designed to teach adults and children about the beneficial applications of nuclear technology.

Playing with the several multimedia activities, parents and children learned a bit more about food irradiation, nuclear power generation and natural occurring radiation. Before the exhibition, visitors were inquired about their prior experiences and previous ideas about nuclear science, which were – most often – very negative. Nevertheless, after being introduced to the several beneficial applications of nuclear technology, opinions usually changed. Most visitors demonstrated a special interest in nuclear medicine applications, since they knew a friend or relative with cancer who had benefited from radiopharmaceutical diagnoses. Through mediated visits, the families were given explanations about x-ray equipment and radioisotopes production, as seen in Figure 4.

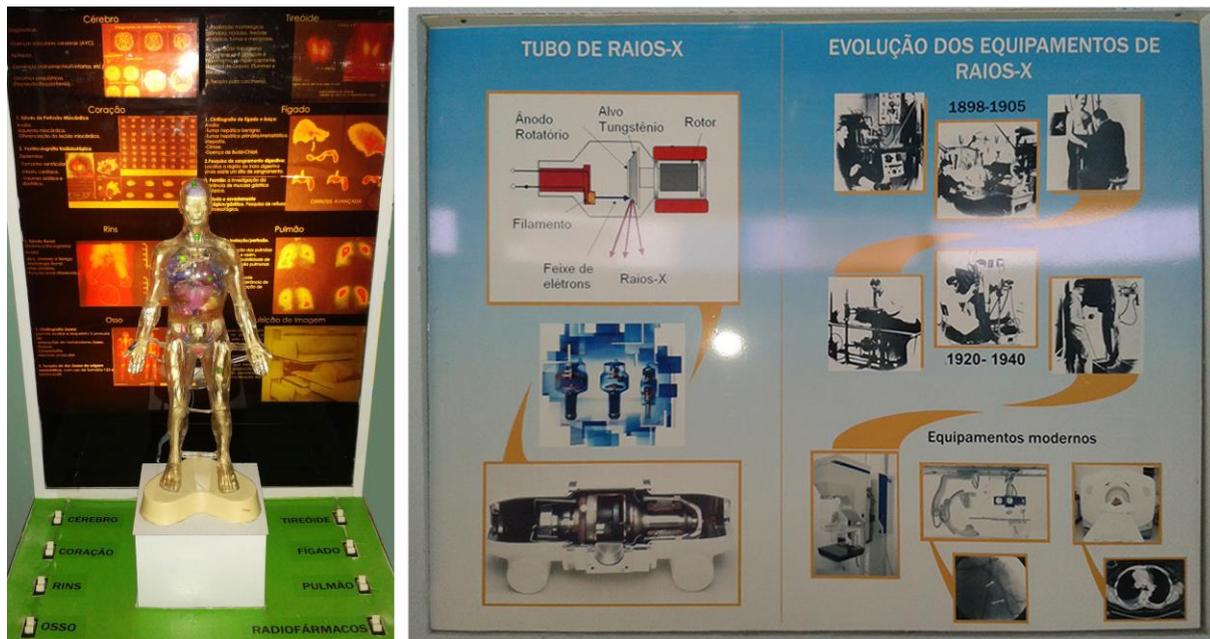


Figure 4. Didactic approaches to inform the general public about the beneficial applications of nuclear sciences

4. CONCLUSIONS

Citizens are expected to understand and discuss social, political, economic, legal and technological issues. Therefore, it is a must to reduce the gap between the highly specialized scientific speech and disseminate knowledge. Information and communication are essential for citizens to evaluate media communications building self-opinions, participating in debates and popular consultations based on reliable information [4]. Even though according to the Brazilian Law of Guidelines and Bases for National Education [1] and to the National Curricular Guidelines for Basic Education [2], schools are responsible for providing the minimum curriculum for a fair comprehension about nuclear technology, teachers themselves are usually not prepared to discuss it deeply.

Both initiatives, the Educational Portal and Nuclear Science Museum offer non-formal learning environments during all year long. In addition, these two initiatives unify efforts during science communication events, such as national thematic weeks.

In order to introduce nuclear sciences in a meaningful contextualized way, all learning actions were designed to promote interdisciplinarity, beyond the often highly specialized scientific speech. Interdisciplinarity involves the combining of two or more research fields into a same perspective, relating nuclear science to Geography, Chemistry, History and Biology, among other disciplines. Nuclear science affects us all, in more ways that the public realizes, from our everyday lives to global issues: food, energy, agriculture, health treatments, and industrial applications. As citizens, people need to form opinions to participate in decision-making processes in our society. It is essential to educate educators – teachers and parents – and engage new generations in this important issue, stimulating their curiosity and encouraging scientific and technological research.

5. ACKNOWLEDGEMENTS

These educational initiatives benefited greatly from the support of a number of individuals and organizations. The Nuclear Energy Museum would like to thank FACEPE (Fundação de Amparo à Ciência e Tecnologia de Pernambuco) for financial support. Educational Portal Radioatividades thanks the support of: Radiological Protection Brazilian Society; Latin American and Caribbean Federation of Radiation Protection Societies; Nuclear Energy Museum; and Brazilian Society of Nuclear Medicine. We expressly thank the international educational networks: LANENT (Red Latinoamericana para la Educación y la Capacitación en Tecnología Nuclear) and CEIDEN (Plataforma Tecnológica de Energía Nuclear de Fisión). Special thanks to Prof. Igor Passos and Prof. Marta Cordeiro for their valuable contributions to improve teacher's content bank.

6. REFERENCES

- [1] "Diretrizes e bases da educação nacional", Lei nº 9.394, de 20 de dezembro de 1996, Brazil http://www.planalto.gov.br/ccivil_03/leis/L9394.htm (2013).
- [2] "Diretrizes Curriculares Nacionais para Educação Básica", Ministério da Educação, Secretaria de Educação Básica, Brazil. <http://portal.mec.gov.br/docman/julho-2013-pdf/13677-diretrizes-educacao-basica-2013-pdf/file> (2013)
- [3] Lucena, et. Al. "Radiação ionizante, energia nuclear e proteção radiológica para a escola", *International Journal of Radiations Sciences*, **Vol 5 (1)**, pp 1-17 (2017)
- [4] "Overview of Information Literacy Resources Worldwide", United Nations Educational, Scientific and Cultural Organization (UNESCO) <http://unesdoc.unesco.org/images/0021/002196/219667e.pdf> (2013)
- [5] "Public Attitudes to Nuclear Power", Nuclear Energy Agency; Organization for Economic Co-operation and development (NEA/OECD). <http://www.oecd-nea.org/ndd/reports/2010/nea6859-public-attitudes.pdf> (2010).
- [6] "FAO - Organização das Nações Unidas para a Alimentação e a Agricultura" <https://nacoesunidas.org/agencia/fao/> (2017)
- [7] Lorenzetti, L. "Alfabetização científica no contexto das series iniciais". *Pesquisa em Educação em Ciência*, **vol. 3 (1)** (2001)